JOURNAL OF SCIENCE EDUCATION AND RESEARCH (JSER)
VOL.8 (3); 2026

EFFECTS OF BRAINSTORMING AND TEAM-PAIR-SOLO INSTRUCTIONAL STRATEGIES ON ACADEMIC ACHIEVEMENT OF BIOLOGY STUDENTS IN OGIDI EDUCATION ZONE

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Abstract

This study investigated Effects of Brainstorming and Team-Pair-Solo Instructional Strategies on Academic Achievement of Biology Students in Ogidi Education Zone, Anambra State. Six research questions and eight hypotheses tested at a 0.05 significance level guided the study. A quasi-experimental research design specifically pretest and posttest non-equivalent control group of 3 X 2 factorial design was adopted. The population of the study comprised 3569 SS2 Biology students, which includes 1709 males and 1860 females in the 30 government-owned secondary schools in Ogidi Education Zone, Anambra State. A sample of 120 (50 males and 70 females) SSII Biology students selected using purposive sampling technique was used for the study. Data were collected using Biology Achievement Test (BAT), validated by three experts, one from the Department of Science Education, one from the Measurement and Evaluation unit of the Department of Educational Foundations, both from Nnamdi Azikiwe University, Awka, and one from an experienced Biology teacher. The reliability of the BAT was established using the Kuder-Richardson Formula 21 (KR-21), yielding a coefficient of 0.76. Data were gathered with the assistance of three trained research assistants. Descriptive statistics (mean and standard deviation) were used to answer the research questions, and ANCOVA was used to test the hypotheses at the 0.05 alpha level. Findings of the study revealed among others that; there was a significant difference in the mean achievement scores of students taught Biology using Brainstorming and Team-Pair-Solo Instructional Strategies (BSIS and TPSIS) and those taught using the Conventional Lecture Method (CLM). Male and female students taught Biology under the BSIS and TPSIS), and CLM did not differ significantly in their academic achievement, with only a marginal difference in post-test mean scores between the genders in both groups. Based on the results, it is recommended that; Schools should incorporate Brainstorming and Team-Pair-Solo Instructional Strategies (BSIS and TPSIS) into their Biology curricula to improve student achievement, professional training programmes should be developed for Biology teachers to facilitate the transition from teacher-centered to BS and TPS strategies, Policymakers and educational authorities should encourage application of BS and TPS strategies across other science subjects.

Keywords: Brainstorming, Team-pair-solo, Academic achievement, Gender

Introduction

Education is a significant means of achieving economic and technological improvement when fully implemented in school and out of school situation. It is a process of learning and training which culminates in changing the perception of an individual for the better. According to the National Policy on Education (Federal Republic of Nigeria, 2014), education is "an instrument for national development and social change," emphasizing its role in equipping individuals with the knowledge and capacity for meaningful societal contribution. No wonder, Asuzu and Okoli (2019) opined that education shapes minds, fosters curiosity, and builds the foundations for thoughtful citizenship.

Science is the study of systematized knowledge produced by careful observation, measurement and experiment, which attempts to establish general laws or principles to describe phenomena under study (Igboegwu, 2022). Science is a dynamic process of seeking for knowledge about nature, acquired through systematic observation and experimentation, which is applied to every aspect of life (Anaekwe, Nzulum, Olisakwe and Okpala in Obialor and Osuafor, 2019). Science comprises basic disciplines or subjects such as physics, chemistry, mathematics and biology therefore it is being offered as one of the science subjects in Nigerian secondary schools.

Biology as a science subject describes how living organism carry out their life activities and how they interact with their environment (Obialor, Ezeobi and Ezenwabuchili, 2020). Biology is very vast with many divisions including zoology, botany, ecology, genetics, morphology, anatomy, physiology, histology, microbiology, biotechnology, evolution, advanced cell biology, and molecular. Obialor, (2016) opined that the study

of biology is essential in a nation's scientific and technological development. Without sound knowledge and wholesome attitude towards biology, the much needed and vouched technological breakthrough may not be achieved, for instance, the knowledge of biology is brought to play in the area of manufacturing and processing industries, biotechnology, genetic engineering, agriculture and horticulture, environmental protection, tourism industry, medicine and pharmacy. It is based on this importance that students are expected to manifest high level of achievement in biology.

Academic Achievement is a measure used to determine what an individual learner is able to do as a result of treatment or exposure to a particular skill or it is an attained knowledge. Stock, (2020) referred academic achievement as the educational outcomes or performance levels that students reach in their academic pursuits, often measured through tests, grades, and assessments. This is to say that students' academic achievement refers to the extent to which a student has attained their short-term or long-term educational goals. It is often measured by performance on standardized tests, classroom grades, and specific learning outcomes. However, it is very disheartening to note that students' performance in this subject (Biology) at both internal and external examinations remained persistently poor.

From the WAEC chief examiner's report 2018-2024, showed that the raw mean scores of students in Biology examinations for seven years interval have never been up to 50 mean score for each year. This is evidence that the academic achievement of secondary school students in Biology is below average 50%. Another evidence of low academic achievement in Biology among secondary school students in Nigeria come as result of

weakness in some Biology concepts as reported by Chief examiners reports from West African Examination Council (WEAC) 2018 – 2024.

Several researchers (Arukoya & Chukwu, 2017; Asuzu &Okoli, 2019; Obialor & Osuafor, 2016) have implicated a number of factors for this unsatisfactory achievement of students in Biology examinations. Some of these factors include; the predominant use of lecture method of teaching by most Biology teachers, unconducive learning environment, non-availability of instructional materials for teaching, absence of equipped Biology laboratories in schools, inadequate science equipment for practical lessons, high teacher-student ratio (large class size) and wide content of secondary school Biology curriculum). Similarly, Uzoma and Okoli (2019) also identified availability of instructional materials, socio-economic background of the students, school environment and use of lecture method of teaching as factors that influence students' achievement in Biology. Obialor (2016) maintained that such teacher-centered approach such as conventional lecture method in which there is steady flow of information going from the teacher to the students does not enhance achievement in science subjects particularly Biology.

Brainstorming is a structured ideation and discussion technique originally popularized by Alex F. Osborn in the mid-20th century and since adapted to classroom settings as an active learning approach. Osborn's formulation emphasized suspending criticism during idea generation to encourage creative contributions. In his quote; "It is easier to tone down a wild idea than to think up a new one". Brainstorming allows students to generate multiple ideas without fear of criticism, stimulating creativity and higher-order thinking (Osuala, 2020). Brainstorming therefore is a collaborative ideation

technique that encourages spontaneous generation of ideas or response to a specific problem or topic in a non-evaluative environment. In classroom use, brainstorming shifts the emphasis from singular correct answers to the volume and diversity of student thinking.

On the other hand, Team–Pair–Solo (TPS) is a cooperative learning strategy where students solve tasks sequentially in teams, pairs, and then individually (Johnson, Johnson, and Smith 2020; Kagan 2018). Team-Pair-Solo (TPS) is a structured cooperative learning model in which students first work in heterogeneous teams, then in pairs, and finally individually on the same task. The scaffolding inherent in TPS allows learners to compare and refine ideas at increasingly independent levels. In the team phase, students benefit from peer explanations and collective reasoning; the pair phase narrows interaction and accountability; and the solo phase assesses individual mastery. The structured stages of TPS enhance peer teaching, collaboration, and independent mastery of concepts, improving achievement in science subjects (Adeyemi, 2020). Furthermore, Team-Pair-Solo (TPS) instructional approach combines group work and individual reflection thus promotes deeper understanding and retention of material, as students articulate their thoughts collaboratively before refining them individually. Therefore, combining brainstorming with TPS instructional strategies or using them in complementary ways is pedagogically attractive for biology students' academic achievement. In line with this suggestion, this study will therefore determine the effect of brainstorming and team pair solo on secondary school students' academic achievement in Biology.

Apart from the teaching methods / strategy used by teachers in teaching the students; gender has also been identified as another factor that affects students' academic achievement and retention in Biology. Gender is referred to as the state of being male or female. It is a social phenomenon that defines masculinity and femininity. According to Okeke in Obialor and Chukwuagu (2022) gender is any physical and behavioral difference between males and females which are social culturally based. However, there is no agreement among researchers on the outcomes of studies on gender effect in biology hence, the issue of gender difference in students' academic achievement in biology is still far from being conclusive. This shows that more work on gender difference in students' academic achievement in biology is still needed. Therefore, it is then against this background that the researcher thought it is necessary to empirically find out the effects of brainstorming, team-pair-solo instructional strategies and gender on secondary school biology students' achievement in Ogidi education zone.

Purpose of the Study

The purpose of this study is to investigate the effects of brainstorming and Team–Pair–Solo instructional strategies on secondary school Biology students' academic achievement in Ogidi Eductional zone.

Specifically, the study seeks to determine the:

1. mean achievement scores of students taught Biology using brainstorming instructional strategy, team-pair-solo and that of those taught with conventional lecture method.

2. mean achievement scores of male and female students taught Biology using brainstorming instructional strategy
3. mean achievement scores of male and female students taught Biology using team-pair-solo instructional strategy
4. Interaction effect of instructional strategies and gender on students' academic achievement in Biology.

Research Questions

The study is guided by the following research questions;

1. What are the mean achievement scores of students taught Biology using brainstorming instructional strategy, team-pair-solo and that of those taught with conventional lecture method?
2. What are the mean achievement scores of male and female students taught Biology using brainstorming instructional strategy?
3. What are the mean achievement scores of male and female students taught Biology using team-pair-solo?

Hypotheses

The following null hypotheses are tested at 0.05 level of significance

1. There is no significant difference in mean achievement scores of students taught Biology using brainstorming instructional strategy, team-pair-solo and that of those taught with conventional lecture method.
2. There is no significant difference in mean achievement scores of male and female students taught Biology using brainstorming instructional strategy.

3. There is no significant difference in mean achievement scores of male and female students taught Biology using team-pair-solo.
4. There is no interaction effect of instructional strategies and gender on students' academic achievement in Biology

Methodology

The study adopted a quasi-experimental design. Specifically, pretest-posttest non-equivalent control group of 3 X 2 factorial designs using intact classes to investigate the effects of brainstorming and Team–Pair–Solo instructional strategies on secondary school Biology students' academic achievement and retention in Ogidi Eductional zone. The study was conducted in Anambra State, Nigeria. The population of the study comprised 3,569 (1709 males and 1860 females) SS2 students offering Biology in the 30-government owned public secondary schools in Ogidi Education Zone. A purposive sampling technique was used to select 120 (50 male and 70 female) SS2 Biology students drawn from three secondary schools out of the eighteen co-educational government owned secondary schools in Idemili North and South Local Government Area, Anambra State. The instrument for data collection was Biology Achievement Test (BAT). The BAT consisted of 50 multiple choice items with four options A-D which were adapted by the researcher from the West African Examination Council (WAEC) past questions and compiled based on the topics taught. For posttest, BAT was reshuffled to produce the versions that was used. The instruments were validated by two experts (lecturers), one from the Department of Science Education, Nnamdi Azikiwe University, Awka, one in Measurement and Evaluation, Department of Educational Foundations, Nnamdi Azikiwe University, Awka and one experienced secondary school biology teacher for face and content validity. The reliability of the

BAT was established using Kudder-Richardson -21 (KR-21). To ascertain its reliability coefficient, the instrument was administered to an intact class of 40 students, similar to the experimental group in one of the schools in Awka Education Zone (outside the zone under study). The coefficient of internal consistency obtained was 0.76 this shows that the instruments were reliable. Data were collected using Biology Achievement and Retention Test (BART) with the assistance of three research assistants. The research questions were answered using mean and standard deviation while ANCOVA was used to test the null hypotheses at 0.05 level of significance using SPSS version 20.

Results

Research Question 1: What are the mean achievement scores of students taught Biology using Brainstorming Instructional Strategy (BIS), Team Pair Solo (TPS) and that of those taught with Conventional Lecture Method (CLM).

Table 1: **Mean Achievement and Standard Deviation scores of students taught Biology using BIS, TPS and CLM**

Group	**N**	**Pretest Mean**	**Pretest *SD***	**Posttest Mean**	**Posttest *SD***	**Gained Mean**
BSIS	40	26.52	4.43	35.70	4.85	9.18
TPS	36	25.78	5.25	35.50	4.64	9.72
CM	44	25.27	4.48	30.18	5.33	4.91

Table 1 shows that the three groups had similar pretest mean scores, indicating comparable achievement before the treatment but the students taught Biology using brainstorming and team-pair-solo instructional strategies had posttest mean achievement scores of 35.70 and 35.50 with gained mean achievement scores of 9.18

and 9.72 respectively while those taught Biology using conventional method had posttest mean achievement scores of 30.18 with gained mean achievement score of 4.91. Students taught Biology using BSIS and TPSIS had higher mean gained achievement scores than those taught using CM.

$H0_1$: There is no significant difference in the mean achievement scores of students taught Biology using BIS, TPS and CLM.

Table 2: ANCOVA Test of Significant Difference in the Mean Achievement Scores of Students taught Biology using BIS, TPS and CLM

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision
Corrected Model	2036.748[a]	6	339.458	19.302	0.000	
Intercept	42.552	1	42.552	2.420	0.123	
Posttest	1031.010	1	1031.010	58.626	0.000	
Method	191.920	2	95.960	5.457	0.005	Sig.
Gender	128.330	1	128.330	7.297	0.008	
Method * Gender	76.134	2	38.067	2.165	0.120	Not Sig.
Error	1987.243	113	17.586			
Total	76005.000	120				
Corrected Total	4023.992	119				

a. R Squared = .506 (Adjusted R Squared = .480)

Data from Table 2 shows that at an F-value of 5.457, the P-value is 0.005. Since the P-value is less than 0.05 level of significance at df of 2 and 113, the null hypothesis is rejected. This reveals that there is a significant difference in the mean achievement scores of students taught Biology using BIS, TPS and CLM. Implying that the achievement of students when taught Biology using BIS, TPS and CLM significantly differ.

Further analysis to determine the direction of the differences among the groups, using Games-Howell post hoc analysis, showed that significant differences occurred among students in the three groups. That is, between BIS and TPS ($p<.05$), BIS and CLM ($p<.05$) as well as between TPS and CLM ($p<.05$), with TPS showing the highest mean difference and followed by BIS. This is shown in Table 3.

Table 3: **Post Hoc Multiple Comparison Analysis of Mean Achievement Differences based on the Three Groups (BIS, TPS and CLM)**

(I) Method	(J) Method	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
BIS	TPS	2.961*	1.067	.019	.41	5.51
	CLM	17.305*	1.087	.000	14.71	19.90
TPS	BIS	-2.961*	1.067	.019	-5.51	-.41
	CLM	14.343*	1.127	.000	11.65	17.04
CLM	BIS	-17.305*	1.087	.000	-19.90	-14.71
	TPS	-14.343*	1.127	.000	-17.04	-11.65

Research Question 2: What is the mean achievement scores of male and female students taught Biology using Brainstorming Instructional Strategy (BIS)

Table 4: **Mean Achievement and Standard Deviation scores of Male and Female students taught Biology using BIS**

Method	Gender	N	Pretest Mean	Pretest *SD*	Posttest Mean	Posttest *SD*	Gained Mean
BSIS	Male	18	25.28	4.40	37.44	4.98	12.16
	Female	22	27.55	4.27	34.27	4.33	6.72
	Diff		-2.27	0.13	3.17	0.65	5.44

As shown in Table 4, that the male students taught Biology using BSIS had pretest mean achievement score of 25.28 and posttest mean achievement score of 37.44 with a gain in mean achievement scores of 12.16 while the female students had pretest mean achievement score of 27.55 and posttest mean achievement score of 34.27 with a gain in mean score of 6.72. Table 2 also reveals that the male students taught Biology with BSIS had higher mean gained achievement score of 12.16 than female students taught Biology using BSIS with mean gained achievement score of 6.72.

$H0_2$: There is no significant difference in the mean achievement scores of male and female students taught Biology using BIS.

Table 5: **ANCOVA Test of Significant Difference in the Mean Achievement Scores of Male and Female Students taught Biology using BIS**

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision
Corrected Model	52.711[a]	2	26.355	1.371	.266	
Intercept	272.276	1	272.276	14.164	.001	
Posttest	1.801	1	1.801	.094	.761	
Gender	50.668	1	50.668	2.636	.113	Not Sig.
Error	711.264	37	19.223			
Total	28907.000	40				
Corrected Total	763.975	39				

a. R Squared = .069 (Adjusted R Squared = .019)

Table 5 data show that at an F-value of 2.636, the P-value is 0.113. Since the P-value, obtained, is greater than 0.05 level of significance at df of 1 and 37, the null hypothesis is not rejected. This reveals that there is no significant difference between the mean achievement scores of male and female students taught Biology using BIS. This

indicates that the use of BIS in teaching Biology promotes their academic achievement irrespective of gender.

Research Question 3: What is the mean achievement scores of male and female students taught Biology using Team-Pair-Solo instructional strategy (TPS)

Table 6: **Mean Achievement and Standard Deviation scores of Male and Female students taught Biology using TPS**

Method	Gender	N	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Gained Mean
TPS	Male	16	25.75	6.02	38.12	3.83	12.37
	Female	20	25.80	4.72	33.40	4.21	7.60
	Diff		-0.05	1.3	4.72	-0.38	4.77

Table 6 shows that the male students taught Biology using TPS had pretest mean achievement score of 25.75 and the female students taught Biology using TPS had pretest of 25.80, indicating similar achievement scores before treatment. Table 6 also reveals that the male students taught Biology with TPS obtained higher posttest mean achievement score of 38.12 with gained achievement mean of 12. 37 than female students taught Biology using TPS with posttest mean achievement score of 33.40 with gained achievement mean of 7.60.

$H0_2$: There is no significant difference in the mean achievement scores of male and female students taught Biology using TPS

Table 7: ANCOVA Test of Significant Difference in the Mean Achievement Scores of Male and Female Students taught Biology using TPS

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision
Corrected Model	254.091[b]	2	127.046	6.549	.004	
Intercept	11.513	1	11.513	.593	.447	
Posttest	222.423	1	222.423	11.465	.002	
Gender	3.186	1	3.186	0.164	.688	Not Sig.
Error	640.214	33	19.400			
Total	26441.000	36				
Corrected Total	894.306	35				

R Squared = .284 (Adjusted R Squared = .241)

Data from Table 7 reveal that at an F-value of 0.164, the obtained P-value is 0.688. Since the P-value is greater than the alpha level of 0.05 at df of 1 and 33, the null hypothesis is not rejected. This shows that there is no significant difference between the mean achievement scores of male and female students taught biology using TPS. Thus, indicating that the use of TPS in teaching students Biology is not gender biased.

$H0_4$: There is no interaction effect of instructional strategies (BIS, TPS and CLM) and gender on students' academic achievement in Biology

Data in Table 2 shows that at an F-value is 2.165, the P-value is 0.120. Since the P-value is greater than 0.05 alpha levels at df 2 and 133, the null hypothesis is not rejected. This affirms that there is no interaction effect of instructional strategies and gender on the academic achievement of students in Biology. Implying that academic achievement of students in Biology in relation to the instructional strategies used is not influenced by students' gender.

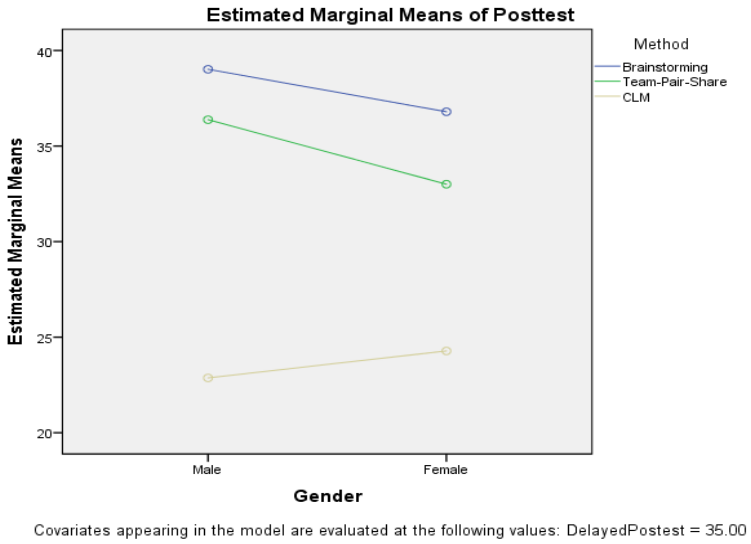


Figure 1: Profile Plot of Interaction Effect of Instructional strategies and Gender on the Achievement of Students in Biology

Discussion

The findings of this study revealed that students taught Biology using the brainstorming instructional strategy achieved significantly higher post-test mean scores than those taught biology using conventional lecture method. The increase in the post-test mean score, together with the positive mean gain recorded by the experimental group indicates that when instruction is supported by an appropriate teaching strategy that actively engage students in the learning process, stimulates critical thinking, promote active participation, collaboration, idea generation and problem solving, students tend to achieve higher academic performance and demonstrate better learning outcome (Obafemi 2024). Furthermore, the relatively low standard deviation observed in the

post-test scores suggests that students benefited from the strategy in a fairly consistent manner, irrespective of their individual differences. The effectiveness of brainstorming can be attributed to its learner-centered nature, which actively involves students in generating ideas, sharing experiences, discussing concepts, and solving biological problems collaboratively (Adewumi, Akanbi and Muraina 2024). During brainstorming sessions, students are encouraged to express their opinions freely without fear of criticism, this creates an interactive classroom environment where learners become active participants rather than passive recipients of information (Onu, Anyaegbunam and Uzoigwe 2020). Such active engagement promotes meaningful learning, improves conceptual understanding, and enhances students' ability to apply biological concepts to real-life situations. Also, Biology being a voluminous subject with complex concepts and often perceived as abstract, students benefit particularly from such strategies because they need opportunities to manipulate ideas and receive immediate feedback. The lecture method, by contrast, often emphasizes teacher explanation and note-taking, which does not necessarily promote active participation. These findings support constructivist learning theory, which emphasizes that learners actively construct knowledge through interaction and collaboration, also are consistent with earlier empirical studies across different subject areas. The findings agree with earlier empirical studies across different subject areas. For instance, Wagbara (2020) conducted a study on the effect of brainstorming instructional strategy on students' academic achievement in senior secondary school in Chemistry in Rivers State, Nigeria, reported that students exposed to brainstorming instructional strategy achieved significantly higher scores than those taught using conventional lecture methods. Similarly, Dajal, Tanko and Orji (2017), in their investigation of the effect of

brainstorming instructional strategy on secondary students' mathematics achievement, found a statistically significant difference in favor of the experimental group. They concluded that brainstorming instructional strategy significantly improved student's achievement. The implication of this findings is, brainstorming and Team-Pair-Solo instructional strategies significantly improved students' academic achievement because it creates more equitable and effective learning environments thereby improving knowledge durability and overall academic performance in Biology.

The findings of the study revealed that both male and female students taught Biology using Brainstorming and Team–Pair–Solo instructional strategies (BSIS and TPS) obtained higher mean gain scores in achievement than their counterparts taught using the lecture method, indicating that the effectiveness of BSIS and TPS cuts across gender lines. This suggests that when learner-centered instructional strategies are effectively implemented both male and female students tend to benefit meaningfully. Biology requires teaching strategies that promote active participation, collaboration, communication, critical thinking, and independent learning among all learners. The lecture method, being largely teacher-centered and passive, may not adequately provide such opportunities for either gender. The higher mean gains recorded for both male and female students exposed to BSIS and TPS therefore indicate that the strategies improve achievement in Biology irrespective of gender differences in learning preferences. The finding that there was no statistically significant interaction effect of instructional strategies (BSIS and TPS) and gender on student's mean achievement scores of male and female students taught Biology using BSIS and TPS further implies that the effectiveness of the Brainstorming and Team–Pair–Solo instructional strategies in improving students' academic achievement were not dependent on whether the

students were male or female. In other words, both male and female students benefited similarly from the instructional strategies, indicating that the strategies were gender-friendly and equally effective for all learners by providing an inclusive learning environment that neutralizes traditional gender-related disparities in classroom achievement as often reported. Such an environment reduces stereotype threat, increases confidence, and promotes equal participation, thereby creating equitable learning opportunities for both male and female students. The absence of a significant interaction effect under BSIS and TPSIS indicates that achievement differences often attributed to gender may instead be linked to the nature of instructional strategies rather than inherent ability differences which may be attributed to the interactive nature of the instructional strategies. Brainstorming encourages students to contribute ideas freely without fear of criticism, thereby increasing confidence and participation among both male and female students. Likewise, the Team–Pair–Solo instructional strategy gradually develops learners' independence through cooperative learning, allowing every student to receive peer support before solving problems individually. These characteristics minimize gender disparities.

These findings align with earlier research on gender and achievement. Oghenevwede (2025) examined gender and interest, ascertained no significant difference in the students' mean scores. Similarly, Wosu (2023) also ascertained that there was no significant difference in the achievement of male and female students suggesting that when instructional conditions are supportive and engaging, male and female students achieve comparably irrespective of gender. Such studies maintained that collaborative and student-centered instructional strategy provide equal learning opportunities for both male and female learners. However, the finding disagrees with studies that

reported significant interaction effects between instructional strategy and gender, suggesting that males or females benefited more from particular instructional strategy. The disparity may be due to differences in sample characteristics, subject content, school environment, teachers' competence, and geographical location. Overall, the finding demonstrates that both Brainstorming and Team–Pair–Solo instructional strategies are effective instructional strategies for improving Biology achievement without favoring any gender group hence gender does not significantly determine Achievement in Biology.

The study found that students exposed to the Team-Pair-Solo (TPS) instructional strategy obtained significantly higher post-test mean achievement scores than those taught using conventional lecture methods. The substantial mean gain recorded by the TPS group indicates that the strategy effectively improved students' academic achievement in Biology. The relatively small post-test standard deviation further suggests that the strategy benefited students across different ability levels. The superiority of the Team-Pair-Solo strategy may be attributed to its structured progression from cooperative learning to independent learning. Initially, students solve problems in groups where they benefit from peer support and shared ideas. They subsequently work in pairs, allowing them to consolidate their understanding while receiving immediate feedback from a partner. Finally, they solve similar tasks independently, thereby developing confidence, mastery, and self-reliance. The gradual release of responsibility embedded in the Team-Pair-Solo strategy enables students to internalize biological concepts before applying them independently. This learning sequence promotes higher-order thinking skills, improves problem-solving abilities, and strengthens conceptual understanding.

The ANCOVA analysis revealed that the difference in achievement between students taught using Team-Pair-Solo and those taught using conventional methods was statistically significant after adjusting for pretest scores. This indicates that the instructional strategy was responsible for the observed improvement in students' academic achievement. The finding is consistent with Vygotsky's Social Constructivist Theory particularly the concept of the Zone of Proximal Development which emphasizes that learners achieve higher levels of understanding through guided interaction before attaining independent mastery. The findings, also are consistent with earlier empirical studies across different subject areas. For instance, Sojionu et al (2024) conducted a study on the effect of Team-Pair-Solo instructional strategy on students' academic achievement in senior secondary school in Mathematics in Lagos State, Nigeria, reported that students exposed to Team-Pair-Solo instructional strategy achieved significantly higher scores than those taught using conventional lecture methods. Similarly, Macmillan and Alhamadu (2020), in their investigation of the effect of Team-Pair-Solo instructional strategy on secondary students' Physics achievement, found a statistically significant difference compared to those taught using conventional lecture method suggesting that Team-Pair-Solo instructional strategy significantly enhances students' achievement because it combines collaborative learning with individual accountability.

Conclusion

Based on the findings of this study, Brainstorming and Team-Pair-Solo instructional strategies is more effective than the conventional lecture method in improving secondary school students' academic achievement in Biology. It further concluded that

by aligning instruction with appropriate teaching strategies that actively engage students in the learning process, stimulates critical thinking, promote active participation, collaboration, idea generation and problem solving, students tend to achieve higher academic performance irrespective of gender differences. Brainstorming and Team-Pair-Solo instructional strategies enhances cognitive processing and thus, leads to significantly improved learning outcomes.

Recommendations

Based on the findings of the study, the following recommendations are made:

1. Biology teachers should regularly incorporate brainstorming and Team-Pair-Solo instructional strategies in their classroom practice in order to ensure equal opportunities for participation of both male and female students which promotes active participation, critical thinking, creativity, independent mastery, collaborative learning and improved academic achievement of Biology concepts thus reducing gender disparities in learning outcomes.
2. Curriculum planners and policymakers should review and restructure Biology curricula and instructional manual to formally incorporate brainstorming and Team-Pair-Solo instructional strategies ensuring that learning activities emphasize learner-centered; active-based, cooperative and collaboration based and real-life applications.
3. Teacher educational authorities and institutions should organize and provide adequate training on learned-centered instructional strategies; regular workshops, seminars, conferences pre- and in-service training programmes to empower teachers

with practical skills and knowledge for designing and delivering lessons in Biology and other science subjects.

4. Government and educational stakeholders should provide adequate instructional materials, conducive learning environments, and supportive classroom facilities that encourage effective implementation of brainstorming and team-pair-solo instructional strategies to foster inclusive learning environments that support sustained academic achievements for all students.

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