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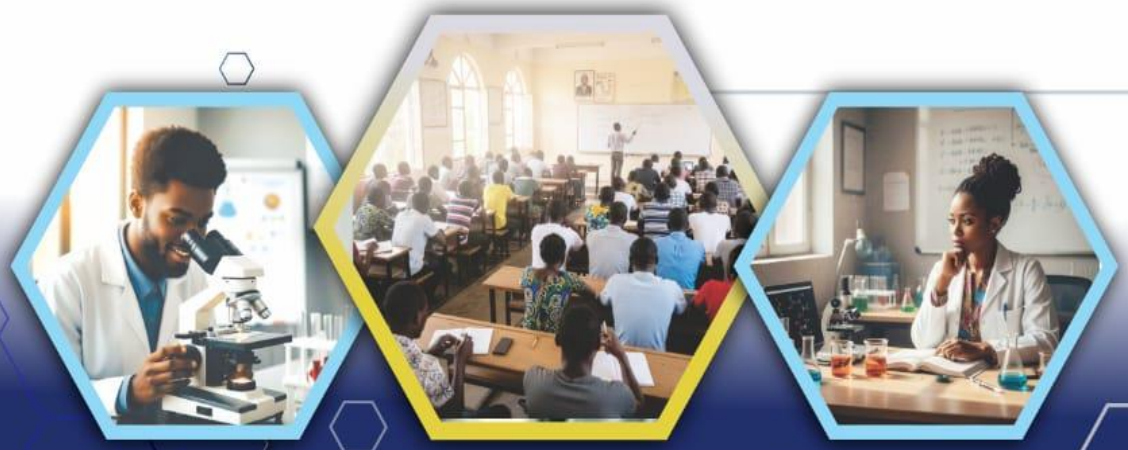

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INTERACTION EFFECT OF FLIPPED CLASSROOM, CANVAS LMS STRATEGIES AND GENDER ON STUDENTS' ACHIEVEMENT AND RETENTION IN PHOTOSYNTHESIS IN SOUTH SENATORIAL DISTRICT, GOMBE STATE, NIGERIA

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Abstract

This study investigated the interaction effect of Flipped Classroom, CANVAS LMS strategies, and gender on students' achievement and retention in photosynthesis in South Senatorial District, Gombe State, Nigeria. Four research questions guided the study, and four null hypotheses were tested at the 0.05 level of significance. A quasi-experimental pre-test, post-test, and post-post-test non-randomized, non-equivalent control group design was adopted. The population comprised 10,605 Senior Secondary One (SS1) students (6,201 males and 4,404 females) in 91 public schools in the district. The sample consisted of 156 SS1 students, including 89 males and 67 females. Data were collected using the Photosynthesis Achievement Test (PAT) and Photosynthesis Retention Test (PRT), which yielded reliability indices of 0.81 and 0.87, respectively, using Kuder-Richardson 21 (KR-21). Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) tested the hypotheses at 0.05 significance level. Results indicated gender did not significantly affect achievement, although female students showed slightly better retention with CANVAS LMS. The interaction between teaching method and gender on retention suggests that engagement behaviors influence long-term learning. Based on these findings, it was recommended that Teachers and school administrators should adopt the Flipped Classroom method for teaching photosynthesis to ensure equal achievement and retention for both male and female students. Education authorities and school management should provide training for teachers on effective use of CANVAS LMS to enhance engagement and learning outcomes across genders.

Keywords: Interaction effect, Flipped Classroom, CANVAS LMS, Photosynthesis, Student Achievement, Gender, Retention.

Introduction

Scientific knowledge and technological innovation remain central pillars of national development because they continually expand our understanding of natural phenomena and supply the techniques required for economic and social advancement (Ajayi & Bello, 2020). In harmony with this perspective, scholars of Biology education maintain that the Nigerian secondary curriculum is structured to provide learners with foundational biological concepts through which they can construct meaningful understanding and develop responsible attitudes toward the environment (Okeke, 2023). It has also been observed that the senior secondary Biology programme seeks to cultivate functional scientific dispositions such as curiosity, objectivity, and problem–solving skills that enable students to interpret life processes in practical contexts (Mohammed & Tanko, 2021). The National Policy on Education further articulates that Biology instruction should encourage the application of scientific processes, promote independent inquiry, and strengthen students' capacity to address real-life challenges while communicating scientific ideas clearly to others (FRN, 2013; Suleiman, 2019). These collective objectives confirm that Biology education is expected to nurture scientifically literate citizens capable of supporting national aspirations in health, agriculture, and technology. Among the topics presented to achieve these goals, photosynthesis stands out as a model concept, offering the basis for understanding plant nutrition, energy transformation, and ecological interdependence.

Photosynthesis is fundamental to the sustainability of life and has for decades been regarded by biologists as the gateway process for energy flow in ecosystems (Johnson, 2018; Adeyemi, 2022). Nevertheless, students in Nigerian secondary schools frequently experience difficulty in comprehending and retaining the concept owing to its abstract vocabulary, multi-stage biochemical character, and limited instructional aids. Researchers identify learners' inability to visualize the light and dark reactions and the experiments associated with them as major barriers to achievement (Emeka et al., 2021; Garba & Yusuf, 2020). Because the topic links the living and non-living worlds and underlies innovations in sustainable agriculture and bioengineering, ensuring effective mastery of photosynthesis is indispensable for the realization of the Biology curriculum goals.

Biology and other science subjects in Nigerian secondary schools continue to be predominantly taught through conventional, teacher-centred methods, where classroom activities are largely limited to passive listening, receptive learning, and rote

memorization (Okafor & Danladi, 2021). These traditional approaches often position the teacher as the sole source of knowledge and provide students with minimal opportunities to participate actively or explore concepts through inquiry. Empirical evidence indicates that learners' achievement in Biology is strongly influenced by the instructional strategies adopted in the classroom, yet the dominant conventional method rarely accommodates individual students' differences or learning needs (Salami, 2023). Consequently, persistent poor performance in Biology has been attributed to ineffective teaching strategies, unfavorable learning habits, and inadequate educational facilities (Garba & Yusuf, 2020).

The integration of digital devices into instruction has been proposed as a pathway for addressing these limitations. Digital tools enable teachers to present lessons using multimedia resources and interactive modules that cannot be effectively delivered through the conventional method (Adebayo, 2022). Research confirms that the use of computer-based multimedia to visualize abstract concepts and processes significantly enhances students' understanding and stimulates active engagement (Emeka et al., 2021). Despite the increasing advocacy for technology-enhanced pedagogy, some proponents of traditional methods continue to search for alternatives without fully embracing the educational possibilities of digital instruction (Suleiman, 2019).

Globally, technology has become a fast-growing delivery platform in educational institutions due to the expanding availability of the internet, computers, smartphones, and educational applications. With advances in teaching aids, instructional strategies have experienced a shift toward more interactive and activity-based learning environments that emphasize collaboration and learner autonomy (Elkhidir, 2020; Johnson, 2018). In this regard, the Flipped Classroom and CANVAS LMS have emerged as innovative strategies for stimulating effective Biology teaching. The flipped classroom model reverses the traditional environment by delivering pre-recorded lectures outside the classroom, while class time is devoted to discussions, exercises, and problem-solving (Mohammed & Tanko, 2021). Studies show that this approach offers diverse learning opportunities and allows teachers to tailor instruction to students' varying levels of expertise (Birgili et al., 2021; Goedhart et al., 2019).

Similarly, CANVAS LMS provides an online platform for teacher–student interaction, monitoring of learning progress, and management of time beyond the classroom. Both CANVAS e-learning and flipped classroom approaches play positive roles in facilitating the learning process, influencing

students' attitudes, and enhancing the quality and efficiency of classroom instruction (Shi & Zhang, 2023; Tuan, 2023). Because photosynthesis involves complex physiological and biochemical stages that students find difficult to visualize, reliance on conventional methods weakens comprehension and long-term retention (Adeyemi, 2022). Given the relevance of photosynthesis to plant nutrition, ecology, and sustainable agriculture, adopting technology-supported strategies is essential for improving students' achievement and retention and for ensuring that Biology curriculum goals are realized in Nigerian schools (Ukala, 2018).

Gender has also been examined as a factor in academic achievement, yet findings remain mixed. Several studies report that gender does not significantly influence learners' performance in Biology when innovative strategies are employed (Ibe & Abamuche, 2019; Ojo et al., 2024). It is against this backdrop of pedagogical shortcomings and the need for gender-inclusive innovation that this study investigated the effects of Flipped Classroom and CANVAS LMS strategies on students' achievement and retention in photosynthesis in the South Senatorial District of Gombe State, Nigeria (Okeke, 2023).

The interaction effect of Flipped Classroom, CANVAS Learning Management System strategies, and gender on students' achievement and retention in photosynthesis has become an important focus in contemporary Biology education, particularly in Nigerian secondary schools where technology–enhanced pedagogy is still emerging. Understanding whether male and female learners respond differently when exposed to these innovative instructional models is essential for confirming the gender inclusiveness and effectiveness of digital approaches. Research on instructional strategy demonstrates that learning outcomes are not shaped by single factors alone but by the dynamic interplay between teaching method, learner characteristics, and the classroom environment. The flipped classroom and CANVAS LMS offer students opportunities for self-paced study, visualization of abstract processes, and collaborative knowledge construction, which may interact with gender-related learning preferences to influence concept mastery and long-term memory. Examining this combined influence provides empirical evidence on how these strategies operate across diverse learners in the South Senatorial District of Gombe State and helps determine whether achievement and retention gains are consistent for all students irrespective of gender.

Statement of the Problem

The mastery of fundamental scientific concepts is a critical goal of biology education in secondary schools, as it equips students with the knowledge and skills necessary to understand natural phenomena and solve real-world problems. Central to achieving this goal is the adoption of effective instructional strategies that actively engage students in the learning process. However, in many Nigerian secondary schools, biology particularly complex topics such as photosynthesis is still largely delivered through conventional teacher-centered approaches, including demonstration, controlled questioning, dictation, board writing, and oral explanation. Such methods often constrain students' participation, limit critical thinking, and place the teacher rather than the learner at the center of instruction. Despite the pivotal role of photosynthesis in the biology curriculum, students' performance in this topic continues to be unsatisfactory, with many exhibiting poor understanding and low retention of essential concepts. This recurring underachievement has negative implications for overall academic performance in biology and related science subjects. While previous studies have explored strategies such as cooperative learning, peer tutoring, and other innovative approaches to improve students' achievement and retention, there remains a pressing need for instructional methods that are both effective and sustainable, particularly those leveraging technology to enhance learning outcomes.

In modern educational settings, students increasingly engage with digital content, often preferring interactive videos and online activities to traditional reading assignments. The integration of digital instructional tools with student-centered pedagogies offers a promising avenue for enhancing engagement, fostering deeper understanding, and improving academic outcomes. Specifically, the flipped classroom model and the Canvas Learning Management System (LMS) provide structured platforms that support active, self-directed learning and have the potential to significantly improve students' achievement and retention in photosynthesis. Moreover, research suggests that students' responses to instructional strategies may differ according to gender, yet evidence on the interaction between teaching methods and gender in the Nigerian secondary school context remains limited. Understanding this dynamic is essential to designing equitable and effective instructional interventions. In view of these challenges, this study seeks to investigate the interaction effects of flipped classroom and Canvas LMS instructional strategies and gender on senior secondary school students' achievement and retention in photosynthesis

in the Southern Senatorial District of Gombe State, Nigeria.

Research Objectives

The aim of this study was to determine the interaction effect of flipped classroom, canvas LMS strategies and gender on students' achievement and retention in photosynthesis in South Senatorial District, Gombe State, Nigeria. Specifically, the objectives of this study were to:

1. ascertain the effect of Flipped classroom strategy on male and female students' achievement in photosynthesis.
2. ascertain the effect of Flipped classroom strategy on male and female students' retention in photosynthesis.
3. determine the interaction effect of teaching methods and gender on students' achievement in photosynthesis.
4. find out the interaction effect of teaching methods and gender on students' retention in photosynthesis.

Research Question

1. What are the mean achievement scores of male and female students' taught photosynthesis using Flipped classroom strategy?
2. What are the mean retention scores of male and female students taught photosynthesis using Flipped classroom strategy?
3. What is the interaction effect of teaching methods and gender on students' achievement in photosynthesis?
4. What is the interaction effect of teaching methods and gender on students' retention in photosynthesis?

Research Hypothesis

Ho_1: There is no significant difference in the mean achievement scores of male and female students taught photosynthesis using Flipped classroom strategy.

Ho_2: There is no significant difference in the mean retention scores of students taught photosynthesis using Flipped classroom strategy.

Ho_3: There is no significant interaction effect of teaching methods and gender on students achievement in photosynthesis.

Ho_4: There is no significant interaction effect of teaching methods and gender on students retention in photosynthesis.

Methodology

This study adopted a quasi-experimental non-equivalent, non-randomized control group design involving pre-test, post-test, and post-post-test measures. The target population comprised 10,605 Senior

Secondary One (SS1) students, consisting of 6,201 males and 4,404 females, drawn from 91 public secondary schools in the South Senatorial District of Gombe State, Nigeria for the 2024/2025 academic session. Gender served as the moderating variable of the study. A sample of 156 SS1 students (89 males and 67 females) from three co-educational secondary schools was selected using purposive sampling based on the availability of functional ICT infrastructure, exposure to digital learning tools, and willingness to participate. Intact SS1 Biology classes within the selected schools constituted the sampling units.

Data were collected using the Photosynthesis Achievement Test (PAT) and the Photosynthesis Retention Test (PRT). The PAT contained two sections: Section A elicited respondents' personal data, while Section B comprised 30 multiple-choice items used for the pre-test and post-test achievement measures. The PRT was administered as the post-post-test to determine retention of photosynthesis concepts. The instruments were validated by three experts from the Department of Science, Technology and Mathematics Education, Nasarawa State University, Keffi, yielding validity indices of 0.82 for PAT and 0.84 for PRT. Trial testing with 30 students outside the main sample produced reliability coefficients of 0.85 and 0.82 for PAT and PRT respectively using Kuder–Richardson 21. Data were analyzed with mean and standard deviation, while ANCOVA was employed for hypotheses testing at the 0.05 level of significance.

Results

Research Question One

What are the mean achievement scores of male and female students' taught photosynthesis using Flipped classroom method?

Table 1: Mean and Standard Deviation on Achievement Scores of Male and Female Students' Taught Photosynthesis Using Flipped Classroom Method

Gender	N	Pre-test		Post-test	
		Mean	S.D	Mean	S.D
Male	30	16.27	3.194	23. 67	2.294
Female	18	15.56	2.791	23.11	2.908

Table 1 shows the results of pre-test and post-test mean achievement scores and standard deviation of male students' taught photosynthesis using flipped classroom

method as (16.27, 3.194) and (23.6, 2.29), while pre-test and post-test mean achievement scores and standard deviation of female students' taught photosynthesis using flipped classroom method are (15.56, 2.79) and (23.11, 2.91) respectively.

Null Hypothesis One

There is no significant difference in the mean achievement scores of male and female students taught photosynthesis using Flipped Classroom method.

The test for hypothesis two is presented in Table 2.

Table 2: Results of ANCOVA on Achievement Scores of Male and Female Students' Taught Photosynthesis Using Flipped Classroom Method

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3.784[a]	2	1.892	0.288	0.752	0.013
Intercept	859.526	1	859.526	130.613	0.000	0.744
Pretest	0.312	1	.312	0.047	0.829	0.001
GenderFC	**3.194**	**1**	**3.194**	**0.485**	**0.490**	**0.011**
Error	296.133	45	6.581			
Total	26714.000	48				
Corrected Total	299.917	47				

a. R Squared = 0.013 (Adjusted R Squared = -0.031)

Table 2 reveals that, there is no significant difference in the mean achievement scores of male and female students taught photosynthesis using Flipped Classroom Method. The value of $F_{(1, 45)} = 0.485$ was obtained with associated exact probability value of 0.490. Since the associated probability of 0.490 was greater than 0.05 level of significance, the null hypothesis two not rejected. The results implied that, there is no gender difference in students' achievement in photosynthesis when they are taught using flipped classroom method.

Research Question Two

What are the mean retention scores of male and female students taught photosynthesis using Flipped classroom method?

Table 3: Mean and Standard Deviation on Retention Scores of Male and Female Students' Taught Photosynthesis Using Flipped Classroom Method

Gender	N	Post test		Post-post test	
		Mean	S.D	Mean	S.D
Male	30	23.67	2.294	20.10	1.561
Female	18	23.11	2.908	20.44	1.097

Table 3 reveals the results of post-test and post post-test mean score and standard deviation of male students' taught photosynthesis using Flipped classroom method as (23.67, 2.29) and (20.10, 1.561), while post-test and post post-test mean scores and standard deviation of female students' taught photosynthesis using Flipped classroom method are (23.11, 2.908) and (20.44, 1.097) respectively.

Null Hypothesis Two

There is no significant difference in mean retention scores of male and female students taught photosynthesis using Flipped classroom method. The test for this hypothesis is presented in Table 4.

Table 4: Results of ANCOVA on Retention Scores of Male and Female Students' Taught Photosynthesis Using Flipped Classroom Method

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1.665[a]	2	0.832	0.412	0.665	0.018
Intercept	237.318	1	237.318	117.595	0.000	0.723
Posttest	0.330	1	0.330	0.163	0.688	0.004
GenderFC	**1.181**	**1**	**1.181**	**0.585**	**0.448**	**0.013**
Error	90.815	45	2.018			
Total	19735.000	48				
Corrected Total	92.479	47				

a. R Squared = 0.018 (Adjusted R Squared = -0.026)

Table 4. reveals that, there is no significant difference in the mean retention scores of male and female students exposed to Flipped Classroom method. The value of $F_{(1, 45)} = 0.585$ is obtained with associated probability value of 0.448 which is greater than 0.05 level of significance, the null hypothesis is not rejected.

Research Question Three

What is the interaction effect of teaching methods and gender on students' achievement in photosynthesis?

Table 5: Mean and Standard Deviation on Interaction Effect on Methods and Gender of Students Achievement Scores in Photosynthesis

Teaching Method	Gender	N	Pre-test Mean	Std. Div.	Post-test Mean	Std. Div.
Flipped C	Male	30	16.27	3.19	23.67	2.30
	Female	18	15.56	2.79	23.11	2.91
CANVAS LMS	Male	27	15.74	4.32	24.44	1.87
	Female	22	16.73	3.01	25.00	2.05

Table 5 reveals that, the pre-test and post-test means and standard deviation on achievement scores of male and female students taught photosynthesis using Flipped Classroom Method are (16.27, 3.19) and (23.67, 2.30), and (15.56, 2.79) and (23.11, 2.91). The pre-test and post-test mean and standard deviation on achievement scores of male and female students taught photosynthesis using CANVAS LMS method are (15.74, 4.32) and (24.44, 1.87), and (16.73, 3.01) & (25.00, 2.05) respectively.

Null Hypothesis Three

There is no significant interaction effect of teaching methods and gender on students' achievement in photosynthesis.

The test for this hypothesis is presented in Table 6.

Table 6: Results of ANCOVA on Achievement Scores of Interaction Effect of Teaching Methods and Gender as Measured by Photosynthesis Achievement Test

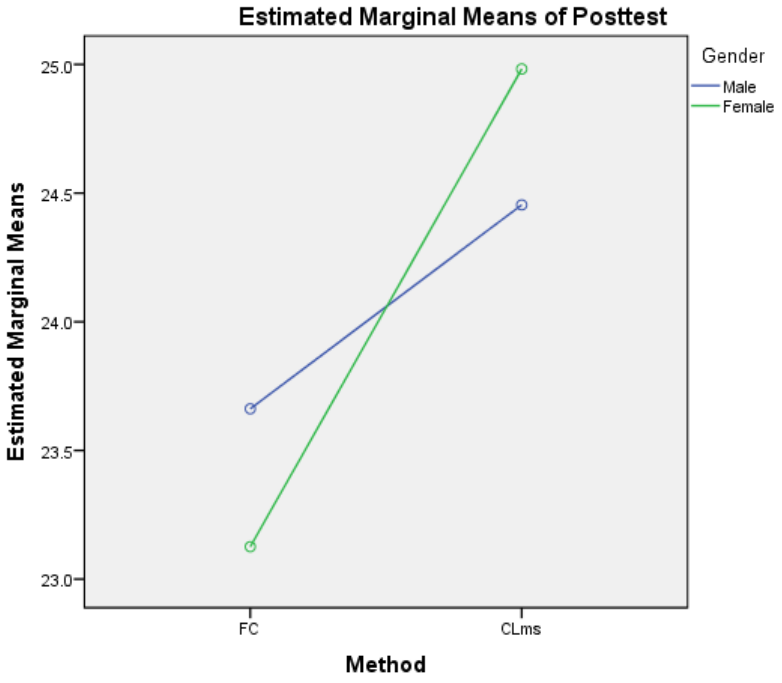
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	45.081[a]	4	11.270	2.186	0.077	0.269
Intercept	2277.530	1	2277.530	441.811	0.000	0.541
Pretest	0.852	1	0.852	0.165	0.685	0.000
Method	40.847	1	40.847	7.924	0.006	0.130
Gender	0.000	1	0.000	0.000	0.994	0.117
Method * Gender	**6.506**	**1**	**6.506**	**1.262**	**0.264**	**0.066**
Error	474.259	92	5.155			
Total	56776.000	97				
Corrected Total	519.340	96				

a. R Squared = 0.087 (Adjusted R Squared = 0.047)

Table 6 shows that, the value of $F_{(1, 92)} = 1.262$ with associated probability value of 0.264 is greater than 0.05 level of significance, the null hypothesis seven is not

rejected. These results indicated that, there is no significant interaction effect of methods and gender as measured by Photosynthesis Achievement Test. This implied that methods and gender have no significant interactions, it means that, teaching method are gender friendly.

The graph of interaction effect between Strategies and gender on achievement is presented in figure 1.



Profile Plots

Figure 1: A Graph Representing Interaction Effect of Teaching Methods and Gender on Photosynthesis Achievement Test

Figure 1 indicates that there is an interaction effect of method with gender to produce high mean achievement scores with the male students scoring higher. CANVAS LMS method interacted with gender to male students' scoring higher than their female. Therefore, the hypothesis of no significant effect is not rejected.

Research Question Four

What is the interaction effect of teaching methods and gender on students' retention in photosynthesis?

The result of the interactive effects is presented in Table 7.

Table 7: Mean and Standard Deviation on Retention Scores of Male and Female Students Taught Photosynthesis Based on Interaction Effects Using Flipped Classroom and CANVAS LMS Methods

Teaching Method	Gender	N	Post-test Mean	Std. Div.	Post-Post-test Mean	Std. Div.
Flipped C	Male	30	23.67	2.29	20.10	1.56
	Female	18	23.11	2.91	20.44	1.20
CANVAS LMS	Male	27	23.44	1.87	20.59	2.58
	Female	22	22.00	2.05	22.86	1.32

Table 7 shows the post-test and post post-test mean scores and standard deviations of male and female students taught Photosynthesis using Flipped classroom method are (23.67, 2.29) & (20.10, 1.56), and (23.11, 2.91) & (20.44, 1.20). The post-test and post post-test means scores and standard deviations of male and female students taught photosynthesis using CANVAS LMS method are (23.44, SD = 1.87) & (20.59, 2.58), and (22.00, 2.05) & (22.86, 1.32) respectively.

Null Hypothesis Four

There is no significant interaction effect of teaching methods and gender on students' retention in photosynthesis.

The test for this hypothesis is presented in Table 8.

Table 8: Results of ANCOVA on Interaction Effect of Teaching Methods and Gender as Measured by Photosynthesis Retention Test

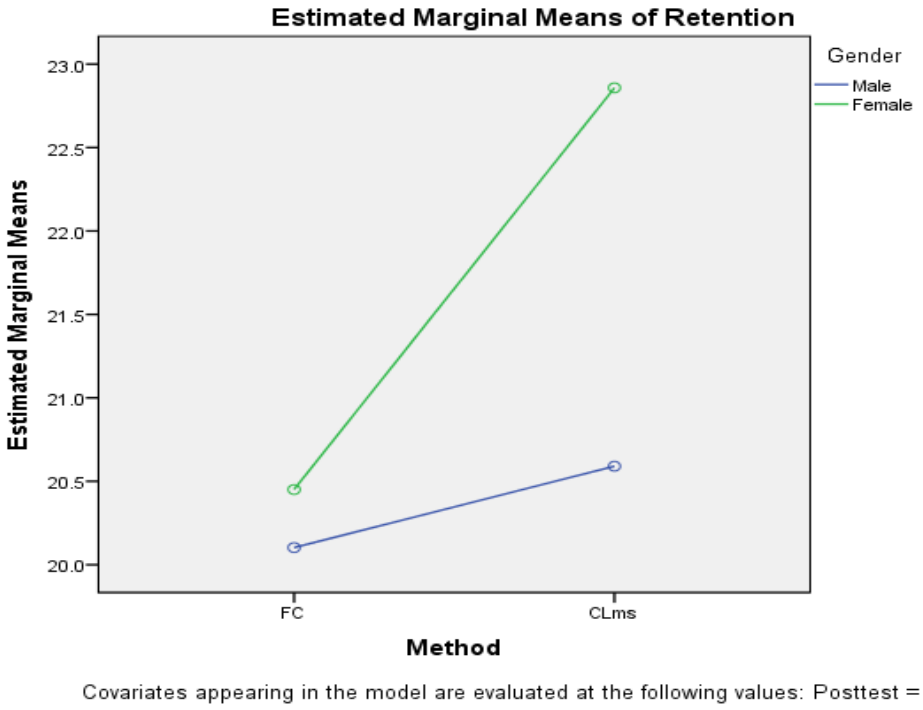
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	110.260[a]	4	27.565	8.447	0.000	0.269
Intercept	353.754	1	353.754	108.400	0.000	0.541
Posttest	0.019	1	0.019	0.006	0.939	0.000
Method	44.974	1	44.974	13.781	0.000	0.130
Gender	39.916	1	39.916	12.231	0.001	0.117
Method * Gender	**21.180**	**1**	**21.180**	**6.490**	**0.013**	**0.066**
Error	300.235	92	3.263			
Total	42894.000	97				
Corrected Total	410.495	96				

a. R Squared = 0.269 (Adjusted R Squared = 0.237)

Table 8 shows that, the value of $F_{(1, 92)} = 0.490$ with associated exact probability value of 0.013 is less than 0.05 level of significance. Since the associated probability

value of 0.013 is less than 0.05 level of significance, therefore, null hypothesis eight is hereby rejected. This indicated that, there is significant interaction effect of students exposed to teaching methods and gender on the mean retention scores. This means that, the teaching methods indicated the significant difference of male and female students, implying that, there is significant interaction effects of methods and gender.

The graph of interaction effect between Strategies and gender on retention is presented in figure 2.



Profile Plots

Figure 2: A Graph Representing Interaction Effect of Teaching Methods and Gender on Mean Retention Scores

Figure 2 indicates that flipped classroom strategy interacted positively with gender, producing higher mean retention scores for female students compared to their male counterparts. This suggests that female students benefitted more from the learner-centered, participatory nature of the flipped classroom approach. In contrast, the CANVAS LMS method yielded generally lower retention scores for both genders, though female students still performed better than males. The pattern indicates that while CANVAS LMS was less effective overall,

gender differences in retention persisted under this method.

Discussion

The findings revealed that there is no significant difference in the achievement scores of male and female students taught photosynthesis using the Flipped Classroom method. This indicates that both male and female students performed equally well when exposed to this student-centered instructional strategy. This outcome aligns with the findings of Gambari, Agboola, and Adeoye (2016), Adonu, Nwagbo, Ugwuanyi, and Okeke (2021), and Femi (2021), who reported that gender did not significantly influence students' performance in biology concepts when taught using flipped classroom strategies. Similarly, Ahmed and Lawal (2020) found that cooperative and interactive learning approaches promoted equitable achievement among male and female students. The lack of gender difference can be attributed to the interactive and engaging nature of the Flipped Classroom. By allowing students to access instructional materials before class and participate actively in learning activities, the method provides equal opportunities for all students to understand and apply concepts. The strategy encourages collaboration, discussion, and self-paced learning, which minimizes gender-related disparities in achievement.

The findings revealed that there is no significant difference in the achievement scores of male and female students exposed to the CANVAS LMS method. This indicates that both male and female students benefited equally from the use of the online learning platform in learning photosynthesis. This outcome is consistent with the findings of Garcia et al. (2020), Kalaw (2022), and Gunarathna, Dayananda, and Ransara (2023), who reported that the use of Learning Management Systems, such as CANVAS, promotes equitable learning outcomes among students regardless of gender. Similarly, Yaprak (2022) and Santiana, Silvani, and Ruslan (2021) found that students' interaction with LMS platforms enhances learning and engagement for all learners, minimizing gender disparities in performance. The equal achievement of male and female students can be attributed to the interactive and accessible nature of CANVAS LMS. The platform allows students to engage with learning materials at their own pace, participate in online discussions, and receive timely feedback. These features create a learning environment where all students have equal opportunities to understand and apply concepts, reducing potential gender-based differences in achievement.

The findings revealed that there is no significant difference in the retention scores of male and female students exposed to the Flipped Classroom method. This indicates that both male and female students retained the concept of photosynthesis equally well when taught using this student-centered instructional strategy. This outcome aligns with the findings of Gambari, Agboola, and Adeoye (2016), Adonu, Nwagbo, Ugwuanyi, and Okeke (2021), and Diepiribo and Zipamone (2024), who reported that gender does not significantly influence students' retention of biology concepts when taught using flipped classroom strategies. Similarly, Femi (2021) found that the interactive and engaging nature of flipped classroom promotes equitable learning and retention among both male and female students. The equal retention of male and female students can be attributed to the Flipped Classroom's focus on active engagement, collaboration, and repeated exposure to instructional materials. By allowing students to review content before class and participate in hands-on, discussion-based learning during class, the strategy provides all students with equal opportunities to understand and internalize concepts, reducing gender-related differences in retention.

The findings revealed that there is a significant difference in the retention scores of male and female students exposed to the CANVAS LMS method, with female students retaining the concept of photosynthesis better than their male counterparts. This outcome aligns with studies suggesting that female students often engage more actively with online learning platforms and digital resources, which may enhance their understanding and retention of concepts (Kalaw, 2022; Santiana, Silvani, & Ruslan, 2021; Gunarathna, Dayananda, & Ransara, 2023). The interactive features of CANVAS LMS, such as discussion forums, quizzes, and continuous access to learning materials, may have provided female students with additional opportunities to process and internalize the content more effectively. The observed gender difference may also reflect differences in learning behaviors, where female students tend to be more meticulous in reviewing materials and participating in online interactions. This increased engagement can contribute to higher retention levels when using technology-enhanced learning platforms.

The findings revealed that there is no significant interaction effect between teaching methods and gender on students' achievement in photosynthesis. This indicates that the effectiveness of the Flipped Classroom, CANVAS LMS, and Conventional Methods is not influenced by whether a student is male or female. In other words, all the teaching methods used in the

study are gender-friendly and promote equitable learning outcomes. This outcome is consistent with the findings of Adonu, Nwagbo, Ugwuanyi, and Okeke (2021), Gambari, Agboola, and Adeoye (2016), and Femi (2021), who reported that flipped classroom and technology-enhanced instructional strategies positively impact students' achievement regardless of gender. Similarly, Garcia et al. (2020) and Kalaw (2022) observed that learning management systems like CANVAS facilitate equal learning opportunities for both male and female students, minimizing gender-based differences in academic performance. The absence of a significant interaction effect can be attributed to the student-centered and inclusive nature of the Flipped Classroom and CANVAS LMS approaches. These methods provide all students with equal access to instructional resources, opportunities for collaboration, and engagement in learning activities, which ensures that achievement outcomes are not biased by gender.

The findings revealed that there is a significant interaction effect between teaching methods and gender on students' retention of photosynthesis concepts. This indicates that the effectiveness of the Flipped Classroom, CANVAS LMS, and Conventional Methods on retention varies between male and female students. In other words, gender plays a role in how students retain information depending on the instructional strategy used. This outcome aligns with studies suggesting that female students may engage more effectively with digital and interactive learning environments, leading to higher retention when using technology-enhanced methods like CANVAS LMS (Kalaw, 2022; Santiana, Silvani, & Ruslan, 2021; Gunarathna, Dayananda, & Ransara, 2023). Similarly, research on Flipped Classroom strategies (Adonu, Nwagbo, Ugwuanyi, & Okeke, 2021; Gambari, Agboola, & Adeoye, 2016) indicates that student-centered methods may amplify gender differences in retention when one group is more active or consistent in reviewing materials outside class. The interaction effect observed suggests that teaching methods are not equally effective for male and female students in terms of retention. Female students appear to benefit more from interactive, technology-driven approaches, whereas male students may require additional support or engagement strategies to achieve comparable retention outcomes.

Conclusion

The study concludes that the Flipped Classroom and CANVAS LMS instructional approaches are largely inclusive and gender-friendly in teaching photosynthesis. Both male and female students achieved equally well under the Flipped Classroom method

and also benefited equally from CANVAS LMS at the achievement level, showing that gender did not significantly hinder understanding when learners had access to materials beforehand, interactive activities, and timely feedback. Nevertheless, female students demonstrated better retention with CANVAS LMS, and a significant interaction effect between teaching methods and gender on retention indicated that long-term learning can vary with engagement behaviors. Therefore, while technology-enhanced strategies minimize gender disparities, teachers should adopt additional support mechanisms especially in LMS-based instruction to strengthen male students' retention and ensure equitable outcomes in biology education.

Recommendations

Based on the findings of this study, it is recommended that:

a. Teachers and school administrators should adopt the Flipped Classroom method for teaching photosynthesis to ensure equal achievement and retention for both male and female students.
b. Education authorities and school management should provide training for teachers on effective use of CANVAS LMS to enhance engagement and learning outcomes across genders.
c. Teachers should implement follow-up activities and reminders for male students during CANVAS LMS instruction to improve their retention of concepts.
d. School administrators and ICT coordinators should ensure reliable internet access and availability of CANVAS LMS materials so all students can participate equally in technology-based learning.

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