



EFFECT OF FLIPPED CLASSROOM INSTRUCTIONAL STRATEGY ON STUDENTS' ACADEMIC ACHIEVEMENT AND INTEREST IN BIOLOGY IN SECONDARY SCHOOLS IN NNEWI EDUCATION ZONE

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Abstract

This study examined the effect of flipped classroom instructional strategy on the academic achievement and interest of secondary school Biology students in Nnewi Education Zone, Anambra State, with gender as a moderating variable. Six research questions and six matching null hypotheses guided the inquiry. A quasi-experimental design involving a pre-test and post-test non-equivalent control group was adopted, since the intact class structure of the sampled schools made full randomisation impossible. The population consisted of 1,322 Senior Secondary School Two Biology students in Ekwusigo Local Government Area. Through multistage sampling, 147 students, comprising 77 in the experimental group and 70 in the control group, were drawn from three schools. Two instruments were used for data collection: the Biology Achievement Test and the Students' Interest in Biology Questionnaire, both validated by experts and found reliable at 0.82 through Kuder-Richardson Formula 20 and Cronbach's Alpha, respectively. Mean and standard deviation answered the research questions, while Analysis of Covariance tested the hypotheses at 0.05 level of significance. Findings revealed that students taught with the flipped classroom strategy achieved higher scores and expressed greater interest than those taught with the conventional lecture method, and that gender neither influenced these outcomes nor interacted with the teaching strategies. Biology teachers are encouraged to adopt the strategy in their classrooms.

Keywords: Flipped Classroom, Instructional Strategy, Academic Achievement, Interest, Biology, Gender

1.1 Introduction

Education remains the deliberate effort through which a society passes on knowledge, skills and values to its members, delivered in stages that move from early childhood through primary,

secondary and tertiary levels. The Federal Republic of Nigeria, in its National Policy on Education, describes secondary education as the stage that prepares young people for useful living in society and for further studies, and charges it with equipping learners with the competencies needed for long-term national development. This places considerable weight on what actually happens inside the secondary school classroom, and it is within this classroom that science subjects, Biology among them, carry out much of that responsibility. Biology occupies a central place in science education because it deals with living organisms, their structure, function and the relationships that bind them to their environment, and Umar, Fugu and Atiju (2018) describe it as one of the subjects through which learners come to appreciate the mechanisms of life itself. Its relevance extends into medicine, agriculture and several allied fields, which is part of the reason Owolabi, Babatunde and Gambari (2019) regard good performance in Biology as non-negotiable, and yet poor performance is precisely what continues to be reported.

Achievement in Biology at the senior secondary level has remained a recurring source of concern among educators, curriculum planners and parents alike. Bichi, Ibrahim and Ibrahim (2019), in their examination of students' performance in the subject, found that a considerable proportion of candidates still fail to obtain the credit pass required for admission into science-related courses at the tertiary level, a pattern that several other researchers working in different parts of Nigeria have also documented. Alongside achievement, interest has increasingly drawn scholarly attention as an equally important outcome of instruction. Interest refers to a learner's curiosity, attention and willingness to engage with a subject, and Kollarou (2025) has observed that students who take a genuine interest in Biology are more inclined to participate in practical work, observe biological processes with care, and connect classroom concepts to everyday experience. Where interest is lacking, Biology tends to be perceived as an overloaded, abstract subject, and this perception leads to low participation and, eventually, low achievement. Emeka and Nwankwo's (2023) recent work reinforces this connection by showing that the instructional strategies teachers adopt in Biology classrooms shape both how students engage with the subject and how well they eventually perform in it, which turns attention toward the instructional methods still in common use.

Much of Biology teaching in Nigerian secondary schools continues to rely on the lecture method or a lightly modified version of it, an approach that places the teacher rather than the learner at the centre of the lesson. Hafeez (2021) has pointed out that this arrangement runs counter to active learning, which contemporary educational thought regards as the more productive framework for instruction, and Minghong, Zhao, Yang and Wang (2019), comparing case-based and traditional teaching in a different educational setting, found the traditional format left learners with fewer opportunities to test, question or apply what they were told, a pattern that resonates with what conventional Biology lecturing produces. Saira and Hafeez (2021), along with Okoye and Onwuachu (2018), link this passivity to some of the very features that make Biology difficult for many students, including an emphasis on memorisation rather than understanding and a general failure to sustain learners' interest across a lesson. Occasional question and answer segments have softened the lecture method without altering its underlying structure, and this has kept the search

open for an instructional approach that can genuinely shift the balance of activity toward the learner. The flipped classroom is one strategy that has emerged from this search.

In a flipped classroom arrangement, students first encounter new content outside the classroom, typically through recorded videos, guided readings or other digital material that they can review at their own pace, and classroom time is then freed for discussion, problem solving and other activities that call for active participation. Hussain, Preetha, Naik and Panaskar (2023) describe this reversal as the defining feature that distinguishes flipped instruction from the conventional sequence in which new material is introduced in class before being practised at home. Smith and Johnson (2020) argue that exposing students to content ahead of time gives them a head start that sharpens their curiosity once they arrive in class, and Martin and Arendale (2021) add that the arrangement opens up a more reciprocal channel of communication between students and teachers, since feedback can now move in both directions rather than flowing only from teacher to learner. Bates and Poole (2022) describe the resulting classroom experience as markedly more active than what conventional lecturing produces, while Lee and Lasky (2019) note that the teacher's role shifts from that of an information source to that of a facilitator who guides discussion and responds to difficulties as they surface. Taken together, these features suggest why Taylor and Russell (2024) found the flipped classroom associated with gains in achievement, motivation and engagement across the subjects in which it has been tried, though the strategy's success, as Bishop and Verleger caution in an earlier but still widely cited analysis, depends heavily on how carefully both the pre-class and in-class components are planned and integrated.

A further consideration that runs through the literature on Biology achievement is gender, and here the picture is far less settled. Some studies, such as that of Ekineh and Adolphus (2019), report no meaningful difference between male and female students once instructional quality and classroom resources are taken into account, which suggests that equitable access to good teaching matters more than gender in shaping outcomes. Other studies point the other way. Eseine-Aloja (2021) found a significant gap favouring male students attending extra-mural Biology classes and traced part of the gap to socio-cultural expectations that leave girls in many Nigerian communities with less time for study after school hours. Sax et al. (2020) add that girls tend to underrate abilities that already match those of boys, while Wang, Degol, Amemiya, Parr and Guo (2020), in their review of classroom climate research, associate the overall learning environment with measurable effects on children's academic wellbeing and confidence. What these findings share is an unresolved question of whether a strategy such as the flipped classroom, once introduced into a mixed classroom, benefits male and female learners to the same degree or produces outcomes that diverge along gender lines.

Despite the growing body of work on flipped instruction in Nigeria, comparatively little of it has focused specifically on Biology at the senior secondary level within Anambra State, and virtually none, to the researcher's knowledge, has examined its effect on both achievement and interest together within Nnewi Education Zone while also accounting for gender. This gap forms the immediate motivation for the present study, which sets out to determine the effect of flipped classroom instructional strategy on the academic achievement and interest of Biology students in

secondary schools in Nnewi Education Zone, and to establish whether gender plays any part in how that effect unfolds.

1.2 Statement of the Problem

Biology holds a firm place among the core science subjects offered at the senior secondary level because of what it feeds into afterward; health sciences, agriculture, environmental management and biotechnology all draw on the foundation it lays. This importance makes the persistently low achievement recorded in the subject difficult to ignore, and it is compounded by a second problem that receives less attention than it deserves: a decline in students' interest in Biology. Interest shapes how much attention a student gives a lesson and how long that student stays with a difficult concept before giving up, so when interest is low the achievement that follows is rarely a surprise.

Part of the explanation lies in how Biology continues to be taught in many secondary schools, where the lecture method still dominates and leaves students largely as recipients rather than participants in their own learning. A classroom run this way tends to make Biology feel abstract and overloaded with facts to be memorised. Learner-centred strategies have been introduced to move away from this pattern, and the flipped classroom is among the more prominent of these, since it allows students to encounter lesson content before class and reserves classroom time for discussion and clarification. In principle, this should raise both achievement and interest, yet how well this holds up for Biology students in Nnewi Education Zone specifically has not been established with empirical evidence.

Gender adds a further layer of uncertainty. Findings on whether male and female students respond differently to Biology instruction remain inconsistent, and it is not yet clear whether the flipped classroom would narrow or simply reproduce whatever gender gap already exists in the subject. Until this is tested directly, teachers and administrators in the zone are left to adopt or avoid the strategy on the strength of assumption rather than evidence. The problem this study addresses, therefore, is the effect of flipped classroom instructional strategy on the academic achievement and interest of Biology students in secondary schools in Nnewi Education Zone, and whether this effect differs for male and female students.

1.3 Research Questions

The following research questions guided the study:

1. What is the difference between the mean achievement scores of Biology students taught using flipped classroom instructional strategy (FCIS) and those taught using the conventional lecture method (CLM)?
2. What is the difference between interest scores of Biology students taught using FCIS and those taught using CLM?
3. What is the difference in the mean achievement scores of male and female students taught Biology using FCIS?
4. What is the difference in the mean interest scores of male and female students taught Biology using FCIS?

5. What is the interaction effect of teaching strategies (FCIS and CLM) and gender on students' achievement in Biology?
6. What is the interaction effect of teaching strategies (FCIS and CLM) on students' interest in Biology?

1.4 Hypotheses

The following null hypotheses were tested at the 0.05 level of significance:

1. There is no significant difference between the mean achievement scores of Biology students taught using flipped classroom instructional strategy (FCIS) and those taught using the conventional lecture method (CLM).
2. There is no significant difference between interest scores of Biology students taught using FCIS and those taught using CLM.
3. There is no significant difference in the mean achievement scores of male and female students taught Biology using FCIS.
4. There is no significant difference in the mean interest scores of male and female students taught Biology using FCIS.
5. There is no significant interaction effect of teaching strategies (FCIS and CLM) and gender on students' achievement in Biology.
6. There is no significant interaction effect of teaching strategies (FCIS and CLM) on students' interest in Biology.

2. Review of Related Literature

The flipped classroom did not emerge in isolation. It draws heavily on Vygotsky's social constructivist theory, which holds that learning is a socially mediated process built through interaction, collaboration and guided support rather than through the solitary absorption of information. Vygotsky's concept of the zone of proximal development, the gap between what a learner can achieve alone and what that learner can achieve with assistance, offers a useful lens for understanding why flipped instruction works the way it does. Students who study lesson content before class arrive already equipped with a preliminary grasp of the material, and this places them well inside the zone where teacher guidance and peer collaboration during class time can push their understanding further. Scaffolding, the structured support that is gradually withdrawn as competence grows, describes much of what happens during the in-class phase of a flipped lesson, and it is this scaffolded, interactive structure that theoretically accounts for both the achievement gains and the heightened interest that flipped instruction is reported to produce.

Empirical work on the flipped classroom in Nigeria has tended to confirm what the theory predicts, though the subjects studied vary. Adebayo and Ogunleye (2022) examined both achievement and interest among Chemistry students in Lagos State and found gains on both measures for the experimental group taught with flipped classroom strategy, which is essentially the same pair of outcomes this study investigates, only in a different science subject. This finding gains further weight from Adewale's (2021) broader observation that students' interest and academic performance in science subjects tend to move together, which supports treating the two outcomes as related rather than independent measures of instructional effectiveness. Closer still to

the present focus, Okeke and Nnamani (2021) studied flipped classroom instruction in Biology in Enugu State and reported higher achievement and interest scores among students exposed to the strategy, while Okeke, Uche, Nwafor and Chukwu (2022), working within Anambra State itself, found a significant achievement advantage for the flipped classroom group using a Biology Achievement Test broadly similar to the one adapted for this study. These Anambra-based findings matter because they narrow the geographic distance between prior evidence and the present investigation, even though neither study examined the specific local government area covered here.

Interest as an outcome has received somewhat less attention than achievement, but the available evidence points in a consistent direction. Nworgu and Eze (2021), working with Biology students in Enugu State, found that flipped classroom instruction improved not only achievement but also retention of Biology content relative to conventional teaching, a pattern that speaks indirectly to the same engagement mechanisms thought to drive interest gains. Taylor and Russell, reviewing evidence across a wider range of subjects, arrived at a similar conclusion, associating flipped instruction with improvements in motivation and engagement alongside achievement, though they caution, echoing an earlier observation by Bishop and Verleger, that these benefits are not automatic and depend on how deliberately the pre-class and in-class components are designed.

The question of gender within flipped classroom research has produced a less settled picture. Bello and Aliyu examined gender differences in Biology achievement under technology-enhanced learning strategies in Kaduna State and found the gap between male and female students to be minimal once the strategy was properly implemented, a result that aligns with the broader argument that equitable instructional strategies tend to narrow rather than widen gender gaps. Working from a different angle, Akingbemisilu (2017) compared animation-based and video-based flipped instruction in practical Biology and found a significant advantage for female students, which suggests that where gender differentiated outcomes do appear under flipped instruction, the specific mode of content delivery, rather than the flipped structure itself, may be the more decisive factor. Jibrin, Mohammed and Zayum (2020), studying cooperative learning rather than the flipped classroom specifically, described their strategy as gender-friendly on the strength of comparable outcomes across male and female students in Bauchi metropolis, offering an indirect point of comparison for how learner centred strategies in general tend to interact with gender.

Taken together, this body of work establishes fairly firm ground for expecting the flipped classroom to raise both achievement and interest in Biology, while leaving the question of gender considerably more open. What remains largely untested, and what this study takes up directly, is whether these patterns hold specifically among Biology students in Nnewi Education Zone, where the local instructional conditions and the specific content area of aquatic and terrestrial habitats have not previously been examined under a flipped classroom arrangement.

3. Methods

This study adopted a quasi-experimental design, specifically a pre-test post-test non-equivalent control group design. Two intact groups of students, an experimental group and a control group, were exposed to different teaching strategies over the course of the study. The experimental group received instruction through the flipped classroom instructional strategy, while the control group was taught the same content using the conventional lecture method. Pre-tests established baseline equivalence between the two groups before treatment began, and post-tests then measured whatever difference the treatment produced in achievement and interest. Creswell and Creswell (2018) describe this design as well suited to educational settings where the existing structure of school classes makes full randomisation impractical, which was the case here since intact SS2 classes rather than individually randomised students had to be used. The study was carried out in Ekwusigo Local Government Area, one of four local government areas that make up Nnewi Education Zone in Anambra State. Ekwusigo was selected in part for this reason and in part because relatively little prior research on flipped classroom instruction in Biology had been conducted there. The population comprised 1,322 SS2 Biology students, 626 male and 696 female, drawn from twenty-eight public co-educational secondary schools across Ekwusigo Local Government Area. SS2 was chosen deliberately because students at this level have already committed to Biology as part of their science combination and are not yet sitting the external West African Senior Secondary Certificate Examination, which made them a suitable group to work with without disrupting examination preparation. A sample of 147 SS2 Biology students, 53 male and 94 female, was drawn from three of the six co-educational secondary schools in the local government area, using a multistage sampling procedure. In the first stage, three schools were purposively selected from the six available, with geographical distance between the schools taken into account to reduce the chance of students in different groups communicating with each other during the study. In the second stage, one SS2 science class was randomly selected from each of the three schools. In the third stage, a coin toss determined which of the schools would serve as the experimental group and which would serve as the control group. This procedure produced an experimental group of 77 students, comprising 28 males and 49 females, and a control group of 70 students, comprising 45 males and 25 females.

Two instruments were used to collect data for the study. The first, the Biology Achievement Test, was compiled by the researcher from past objective questions set by the West African Examinations Council and the National Examinations Council on the topic of aquatic and terrestrial habitats, with a marking key prepared alongside it. The test consisted of two sections, the first collecting personal data such as class and gender, and the second containing fifty multiple-choice items with four options each, scored two marks per item for a total of one hundred marks. The second instrument, the Students' Interest in Biology Questionnaire, was a thirty-item scale designed to measure students' interest, engagement and motivation in Biology lessons, with responses recorded on a four-point scale ranging from strongly agree to strongly disagree. Both instruments were subjected to face and content validation by three experts, two from the Biology Department and one from Educational Foundations with specialisation in measurement and evaluation, and corrections suggested by the validators were incorporated into the final versions. Reliability was established separately for each instrument, using an approach suited to its scoring

format. The Kuder Richardson Formula 20 was applied to the Biology Achievement Test because its items are dichotomously scored, while Cronbach's Alpha was applied to the Interest Questionnaire because it consists of Likert scaled items measuring a single underlying construct. Both instruments were administered to a group of SS2 Biology students drawn from Nnewi North Local Government Area, outside the sampled area of the main study, and the analysis yielded a reliability coefficient of 0.82 for each, comfortably above the 0.70 threshold generally regarded as acceptable for research purposes.

Before the treatment began, research assistants, who were the students' regular Biology teachers, were briefed over a three-day training programme on the procedures of flipped classroom instruction and their role within it. The Biology Achievement Test was then administered to both groups as a pre-test. Over the following three weeks, the experimental group received lesson content in advance through recorded videos shared on a WhatsApp platform created for the study, followed by in-class sessions devoted to discussion and application, while the control group continued to receive instruction through the conventional lecture method. At the end of the treatment period, a reshuffled version of the Biology Achievement Test and the Interest Questionnaire were administered to both groups as post-tests, and the resulting scores were recorded for analysis. Measures were also taken to control extraneous variables that could otherwise have confounded the results, including keeping the two groups physically apart to prevent interaction, withholding the achievement test from teachers except at the point of administration to reduce sensitisation, and ensuring both groups received comparable attention from their regular teachers throughout the study period. Data collected from both instruments were analysed in line with the research questions and hypotheses guiding the study. Mean and standard deviation were used to answer the six research questions, while Analysis of Covariance was used to test the corresponding null hypotheses at the 0.05 level of significance, with the pre-test scores entered as covariates to adjust statistically for whatever initial differences existed between the groups before treatment. A null hypothesis was rejected wherever the associated probability value fell at or below 0.05, and retained wherever it exceeded this threshold.

4. Results

Research Question One: What is the difference between the mean achievement scores of Biology students taught using flipped classroom instructional strategy and those taught using the conventional lecture method?

Table 1: Mean and Standard Deviation of Pre-test and Post-test Achievement Scores by Group

Group	n	Pre-test Mean	Post-test Mean	Mean Gain
Experimental (FCIS)	77	18.25	37.60	19.35
Control (CLM)	70	23.97	29.39	5.42

The experimental group entered the study with a lower pre-test mean than the control group, yet finished with a post-test mean nearly eight marks higher, a reversal that points to a real treatment effect rather than the carrying forward of an initial advantage. The mean gain recorded by the experimental group, at 19.35 marks, was more than three times that of the control group, indicating

that a difference exists between the two groups in favour of students taught with the flipped classroom instructional strategy.

Hypothesis 1: There is no significant difference between the mean achievement scores of Biology students taught using flipped classroom instructional strategy and those taught using the conventional lecture method.

Table 2: One-Way ANCOVA of the Difference in Mean Achievement Scores by Instructional Group

Source	df	F	Sig.
Pre-test Achievement Score	1	0.134	.000
Instructional Group	1	41.789	.000

Note. $R^2 = 0.255$. Covariate: pre-test achievement score.

The instructional group effect returned an F-ratio of 41.789 with a probability value of .000, below the 0.05 threshold, so the first null hypothesis was rejected. This confirms that the difference observed in Table 1 was statistically dependable and not an artefact of chance, even after the pre-test differences between the groups had been statistically controlled for. The adjusted means placed the experimental group at 37.52 against 29.47 for the control group.

This finding is consistent with what Adebayo and Ogunleye (2022) reported when investigating flipped classroom instruction in Chemistry in Lagos State, where the experimental group significantly outperformed the conventionally taught group. It also matches the more geographically relevant work of Okeke, Uche, Nwafor and Chukwu (2022), who found a significant achievement advantage for a flipped classroom group of Biology students within Anambra State itself, though their analysis relied on an independent samples t-test rather than ANCOVA and so did not adjust for pre-existing group differences the way the present analysis did. The consistency across these studies, despite differences in subject and in some cases in statistical technique, strengthens the case that flipped instruction produces a genuine achievement gain rather than one specific to a particular content area or research context.

Research Question Two: What is the difference between interest scores of Biology students taught using FCIS and those taught using CLM?

Table 3: Mean and Standard Deviation of Pre-test and Post-test Interest Scores by Group

Group	n	Pre-test Mean	Post-test Mean	Mean Gain
Experimental (FCIS)	77	74.34	90.56	16.22
Control (CLM)	70	70.84	76.23	5.39

Note. SIBQ scores are out of 120.

Unlike the achievement measure, the two groups began the study with fairly close interest scores, separated by only 3.50 points, yet ended with a gap of 14.33 points favouring the experimental group. The mean gain recorded on the interest measure was, in fact, wider than the gain recorded on achievement, suggesting that the affective benefits of flipped instruction may register more strongly, at least within a five-week treatment window, than its cognitive benefits.

Hypothesis 2: There is no significant difference between interest scores of Biology students taught using FCIS and those taught using CLM.

Table 4: One-Way ANCOVA of the Difference in Interest Scores by Instructional Group

Source	df	F	Sig.
Pre-test Interest Score	1	0.001	.975
Instructional Group	1	71.381	.000

Note. $R^2 = 0.339$. Covariate: pre-test interest score.

The instructional group effect on interest returned an F-ratio of 71.381 at a probability value of .000, leading to the rejection of the second null hypothesis. The adjusted post-test means confirmed the experimental group's advantage, at 90.56 against 76.22 for the control group. This finding sits comfortably alongside Nworgu and Eze's (2021) report that flipped classroom instruction improved Biology students' engagement and retention in Enugu State relative to conventional teaching. Within Biology specifically, Okeke and Nnamani (2021) likewise found higher post-test interest scores among students taught through flipped instruction in Enugu State, lending direct subject-level support to what was found here.

Research Question Three: What is the difference in the mean achievement scores of male and female students taught Biology using FCIS?

Table 5: Mean Achievement Scores of Male and Female Students in the Experimental Group

Gender	n	Pre-test Mean	Post-test Mean	Mean Gain
Female	52	17.63	38.29	20.66
Male	25	19.52	36.16	16.64

Female students entered the study slightly behind their male counterparts but finished 2.13 marks ahead of them, a modest reversal considerably smaller than the 8.21 mark gap recorded between the two instructional groups in Table 1, which suggests gender accounts for far less of the variation in achievement than the teaching strategy itself does.

Hypothesis 3: There is no significant difference in the mean achievement scores of male and female students taught Biology using FCIS.

Table 6: Two-Way ANCOVA of Gender Difference in Achievement within the Experimental Condition

Source	df	F	Sig.
Gender	1	1.171	.281
Instructional Group $\times$ Gender	1	0.007	.932

Note. $R^2 = 0.269$. Covariate: pre-test achievement score.

The main effect of gender produced an F-ratio of 1.171 at a probability value of .281, above the significance threshold, so the third null hypothesis was retained. Male and female students taught

with the flipped classroom strategy achieved at statistically comparable levels, with adjusted means of 36.12 and 38.20 respectively. This mirrors the finding of Okeke, Uche, Nwafor and Chukwu (2022), whose flipped classroom group in Anambra State also showed no significant gender difference in achievement, and it aligns with Bello and Aliyu (2022), who likewise found only a minimal gender gap in Biology achievement under a technology-enhanced strategy in Kaduna State.

Research Question Four: What is the difference in the mean interest scores of male and female students taught Biology using FCIS?

Table 7: Mean Interest Scores of Male and Female Students in the Experimental Group

Gender	n	Pre-test Mean	Post-test Mean
Female	52	75.37	89.98
Male	25	72.20	91.76

Male students recorded a slightly higher post-test interest mean than female students, a difference of 1.78 points that is small relative to the 14.33 point gap between the instructional groups reported earlier.

Hypothesis 4: There is no significant difference in the mean interest scores of male and female students taught Biology using FCIS.

Table 8: Two-Way ANCOVA of Gender Difference in Interest within the Experimental Condition

Source	df	F	Sig.
Gender	1	3.093	.081
Instructional Group × Gender	1	3.083	.081

Note. $R^2 = 0.355$. Covariate: pre-test interest score.

The gender effect on interest produced an F-ratio of 3.093 at a probability value of .081, again above 0.05, so the fourth null hypothesis was retained, with adjusted means of 91.76 for male students and 90.00 for female students indicating statistically comparable levels of interest between the two groups.

Research Question Five: What is the interaction effect of teaching strategies and gender on students' achievement in Biology?

Table 9: Adjusted Mean Achievement Scores by Instructional Group and Gender

Group	Gender	Adjusted Mean
Experimental	Male	36.12
Experimental	Female	38.20
Control	Male	28.34
Control	Female	30.21

The female advantage within the experimental group, at 2.08 marks, was nearly identical to the female advantage within the control group, at 1.87 marks, while the flipped classroom advantage itself stood at 7.78 marks for males and 7.99 marks for females. Both patterns point toward the

two variables operating independently of one another rather than combining to produce a distinct effect.

Hypothesis 5: There is no significant interaction effect of teaching strategies and gender on students' achievement in Biology.

Table 10: Two-Way ANCOVA of the Interaction Effect on Achievement

Source	df	F	Sig.
Instructional Group × Gender	1	0.007	.932

The interaction term returned a probability value of .932, far above the significance threshold, so the fifth null hypothesis was retained. This finding is consistent with the broader pattern reported by Jibrin, Mohammed and Zayum, whose cooperative learning strategy in Bauchi metropolis likewise produced comparable outcomes for male and female Biology students, reinforcing the reading that the advantage recorded for flipped instruction under Research Question One applies without qualification across gender lines.

Research Question Six: What is the interaction effect of teaching strategies and gender on students' interest in Biology?

Table 11: Adjusted Mean Interest Scores by Instructional Group and Gender

Group	Gender	Adjusted Mean
Experimental	Male	91.76
Experimental	Female	90.00
Control	Male	73.68
Control	Female	78.00

The gender gap on interest reversed direction between the two instructional groups: male students led within the experimental group by 1.76 points, while female students led within the control group by roughly 4.32 points. This crossing pattern meant the flipped classroom's interest advantage was somewhat larger for male students than for female students.

Hypothesis 6: There is no significant interaction effect of teaching strategies and gender on students' interest in Biology.

Table 12: Two-Way ANCOVA of the Interaction Effect on Interest

Source	df	F	Sig.
Instructional Group × Gender	1	3.083	.081

The interaction term returned a probability value of .081, which exceeds 0.05, so the sixth null hypothesis was also retained, though the value here sits closer to the significance threshold than any other tested in this study. This visible but statistically inconclusive crossing pattern echoes Akingbemisilu's finding that the specific mode of flipped content delivery can engage male and female students differently in practical Biology, even though the interaction here did not reach conventional significance. A plausible reading is that the imbalance in the experimental group, which contained more than twice as many female as male students, limited the statistical power

available to detect an interaction of this size, a possibility future research with a more evenly distributed sample could test directly.

5. Discussion

Read together, these findings tell a fairly coherent story. Students taught Biology through the flipped classroom instructional strategy achieved higher scores and expressed greater interest than those taught through the conventional lecture method, and both differences held up after the pre-test scores had been statistically controlled, which rules out the possibility that the results simply reflect whichever group happened to start stronger. This pattern is consistent with the theoretical expectation drawn from Vygotsky's social constructivist theory, since the flipped arrangement placed students within their zone of proximal development by giving them a preliminary grasp of the content before class, then used classroom time for the scaffolded, collaborative activity through which deeper understanding and sustained interest are theorised to develop.

The comparison with prior Nigerian studies strengthens rather than complicates this reading. Adebayo and Ogunleye's Chemistry findings and Okeke and Nnamani's Biology findings all point in the same direction, and the two studies conducted within Anambra State itself, Okeke, Uche, Nwafor and Chukwu on achievement and the present study on both achievement and interest, agree closely despite differing in local government area and in statistical approach. Where the present study extends this literature is in its joint treatment of achievement and interest alongside gender within a single design, and in its use of ANCOVA throughout rather than the independent samples t-test some earlier studies relied on, which allows initial group differences to be statistically accounted for rather than assumed away.

On gender, the absence of a significant main effect and the absence of a significant interaction on achievement mean the flipped classroom strategy can reasonably be described as gender neutral in its effect on Biology achievement within this sample, a description that lines up with what Bello and Aliyu and, in a related instructional context, Jibrin, Mohammed and Zayum have reported. The picture of interest is less tidy. The interaction term approached, without crossing, the conventional significance threshold, and the crossing pattern visible in the adjusted means, where male students showed a larger flipped classroom advantage than female students, is worth taking seriously even though it did not reach statistical significance here. Akingbemisilu's finding that content modality can produce gender differentiated outcomes under flipped instruction offers one plausible explanation, and the gender imbalance within the present experimental group offers another, more methodological one. Neither explanation can be confirmed on the strength of this data alone, which is itself a useful finding, since it identifies a specific direction, a more gender balanced sample examining the interest outcome, for future research to pursue.

6. Conclusion

On the strength of these findings, the flipped classroom instructional strategy proved more effective than the conventional lecture method for teaching Biology to SS2 students in Nnewi Education Zone. Students taught through the strategy achieved significantly higher scores and

expressed significantly greater interest in the subject than their counterparts taught through the conventional method, and both differences remained significant once pre-test scores had been statistically controlled. Gender neither significantly influenced achievement nor interest within the flipped classroom group, nor did it interact significantly with the teaching strategies applied to either outcome, indicating that the strategy's benefits were not confined to one gender group. The flipped classroom instructional strategy, on this evidence, improves both the achievement and the interest of Biology students in Nnewi Education Zone, and it appears to do so for male and female students alike.

7. Recommendations

Based on these findings, the following recommendations are made. Biology teachers in Nnewi Education Zone should adopt the flipped classroom instructional strategy by providing students with pre-recorded video lessons or digital reading materials to study before class, reserving class time for discussion, problem solving and clarification of difficult concepts. Teachers should structure the in-class component of flipped lessons around active tasks rather than a repeat of the pre-class content, since it is this component that appears to drive much of the gain in both achievement and interest. Given the absence of a significant gender effect, teachers in co-educational classrooms should implement the strategy uniformly for male and female students rather than developing separate versions of the pre-class materials. School administrators should support this shift by providing the basic digital infrastructure, reliable network access and short WhatsApp or similar platform-based delivery that the strategy depends on, along with training for teachers on how to prepare pre-class video content. Curriculum planners and education authorities within the zone might also consider incorporating flipped instructional guidance into the Biology scheme of work, particularly for topics that Chief Examiners' reports have flagged as consistently difficult for students, such as aquatic and terrestrial habitats.

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