Flipped classroom instructional strategy and secondary school students' academic achievement in Biology: a quasi-experimental study

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Abstract. This study compared the achievement in Biology of senior secondary school students taught with the flipped classroom instructional strategy (FCIS) and those taught with the conventional lecture method (CLM) in the Awka Education Zone of Anambra State, Nigeria. A pretest–post-test non-randomised control group quasi-experimental design was used with intact classes of senior secondary two (SS2) students in two co-educational public schools: 86 students in all, 44 taught with FCIS and 42 with CLM. Achievement was measured with a 50-item multiple-choice Biology Achievement Test adapted from 2019–2025 West African Examinations Council (WAEC) and National Examinations Council (NECO) papers (KR-20 = 0.75). Tests were computed from the reported group summary statistics and are not adjusted for pretest scores. The groups did not differ significantly at pretest. On the post-test, the FCIS group scored higher than the CLM group (78.43 vs 65.82; difference 12.61, 95% CI 8.46 to 16.75, $p < 0.001$, Hedges' $g = 1.29$), and its mean gain was 50.59 against 40.69. Male and female students did not differ significantly in either group, and the interaction of teaching method and gender was not significant. Secondary schools may consider using FCIS in Biology, supported by teacher training and access to the technology it requires.

Keywords: academic achievement, biology, flipped classroom, conventional lecture method

1. Introduction

Biology gives students knowledge of the structures and functions of living organisms and of their interactions with the environment [6], including how the human body works, heredity and the prevention of disease. This knowledge bears on public health, food security and conservation, and in Nigeria Biology is central to disciplines such as Medicine, Nursing, Pharmacy and Microbiology [7].

Academic achievement is the extent to which students attain educational goals, usually measured through grades, scores on teacher-made or standardised tests, and coursework [9, 10]. One of the factors that influence it is teaching method: the way a teacher presents lessons, guides students towards learning goals and uses the available materials.

The conventional lecture method (CLM), which is teacher-centred and predominant in Nigerian schools, has been observed to limit practical work and hands-on learning [2]. The flipped classroom instructional strategy (FCIS) reverses the usual order of the lecture method, in which students meet new concepts in class and practise them at home. Under FCIS, students study new concepts at home through videos, screencasts or directed reading and then apply them in class through discussion, presentations, debates or laboratory work [16], which moves the focus from teacher-centred delivery of content to student-centred construction of knowledge [8].

Research on the flipped classroom includes a review of its advantages and challenges [3] and a meta-analysis that found improved learning in health professions education [8]. Studies, several of

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Received 2026-02-17 Accepted 2026-07-06 Published 2026-11-16

Science Education Quarterly

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them in Nigeria, have examined the strategy in Biology [13], genetics [1, 14], Chemistry [5, 17], Mathematics [12] and English Language [16]. Ogunleye et al. [13] and Nwoke, Mang and Onuoha [12] report that it improved students' understanding and performance in Biology and Mathematics, respectively. In the Awka Education Zone, a study involving Biology examined teachers' knowledge and use of flipped learning [15] rather than the effect of the strategy on students' achievement, which the present study examines.

Gender refers to the socially constructed, learned and context-specific roles, behaviours and attributes that a society considers appropriate for men and women [18]. Such perceptions can affect students' enrolment and achievement in science, and findings on gender differences are mixed. Almasri [4] found that female students often outperformed male students in science subjects, and Musa, Ozoji and Duru [11] presented Vee mapping as a gender-responsive technique for improving science achievement. Ibeh and Okigbo [9] found that males scored higher than females under a jigsaw learning strategy and females higher under the lecture method, with neither difference significant, and Abbas and Idris [1] found no significant difference between male and female students taught genetics with the flipped classroom. Gender was therefore included as a possible moderating variable.

The study addressed three research questions:

1. What is the difference between the mean achievement scores in Biology of students taught with FCIS and those taught with CLM?
2. What is the difference between the mean achievement scores in Biology of male and female students taught with FCIS, and of those taught with CLM?
3. What is the interaction effect of teaching method and gender on students' achievement in Biology?

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

H_{01}: There is no significant difference between the mean achievement scores in Biology of students taught with FCIS and those taught with CLM.

H_{02}: There is no significant difference between the mean achievement scores in Biology of male and female students taught with FCIS, or of those taught with CLM.

H_{03}: There is no significant interaction effect of teaching method and gender on students' achievement in Biology.

2. Methods

2.1. Design and participants

The study used a pretest–post-test non-randomised control group quasi-experimental design in government-owned secondary schools in the Awka Education Zone of Anambra State, Nigeria. Intact classes were used in each school to form the experimental and control groups. The population was 3,891 senior secondary two (SS2) students offering Biology in the 65 public secondary schools of the zone's five Local Government Areas. Two co-educational schools offering Biology were selected purposively, giving a sample of 86 SS2 students. The FCIS group had 44 students (21 male, 23 female) and the CLM group 42 (23 male, 19 female).

2.2. Instrument

Achievement was measured with the Biology Achievement Test (BAT), consisting of 50 multiple-choice items on the respiratory system, the excretory system and homeostasis, adapted from 2019–2025 past papers of the West African Examinations Council (WAEC) and the National Examinations Council

(NECO). Each correct answer scored 2 marks and each incorrect answer 0. Three experts from the Departments of Science Education, Educational Foundations (Measurement and Evaluation) and Biology at Nnamdi Azikiwe University, Awka, validated the BAT against the test blueprint. Its reliability, estimated with Kuder–Richardson Formula 20 (KR-20), was 0.75.

2.3. Procedure

The regular Biology teachers in the sampled schools served as research assistants and were trained in FCIS and CLM with researcher-developed lesson plans and a training manual. The intervention lasted six weeks: one week for the pretest, four weeks of teaching, and one week for revision and the post-test.

In the pre-class phase of FCIS, instructional videos, the teachers' audio explanations, PowerPoint presentations, PDF notes and directed readings were posted to a class WhatsApp group created for the study. Students studied the materials at home and, before each class, sent the teacher a completed short quiz on the concepts by private WhatsApp message. In class, students worked on group discussions, collaborative tasks, problem-solving activities and practical exercises, while the teacher clarified difficult concepts, guided discussion, monitored participation and gave feedback. The CLM group was taught by lecture, with verbal explanation, note writing and demonstrations; students listened, copied notes and asked questions.

2.4. Data analysis

Means and standard deviations were used to answer the research questions. Individual scores are not reported, so the hypothesis tests were computed from the group summary statistics in table 1 and are not adjusted for pretest scores. Differences between methods at pretest and post-test (H_{01}), and between male and female students within each method (H_{02}), were tested with Welch's t-test, with Hedges' g as the effect size. The interaction of method and gender (H_{03}) was tested with a 2×2 analysis of variance on post-test scores computed from the cell means, standard deviations and sizes, with partial η^2 as the effect size. Mean gains (post-test minus pretest) are reported descriptively, because their standard deviations are not available. A null hypothesis was rejected when $p < 0.05$ and was otherwise not rejected.

Table 1
Pretest and post-test achievement scores in Biology by teaching method and gender. The rows labelled "All" are pooled from the male and female rows.

			Pretest		Post-test		
Method	**Gender**	***n***	**Mean**	**SD**	**Mean**	**SD**	**Mean gain**
FCIS	Male	21	27.64	7.61	77.89	10.27	50.25
	Female	23	28.03	7.43	78.92	9.82	50.89
	All	44	27.84	7.43	78.43	9.93	50.59
CLM	Male	23	25.03	6.01	66.57	9.03	41.54
	Female	19	25.26	6.21	64.92	9.98	39.66
	All	42	25.13	6.03	65.82	9.39	40.69
FCIS − CLM (All)			2.71		12.61		9.90

3. Results

3.1. Teaching method and achievement

Both groups improved from pretest to post-test (table 1). The FCIS group's mean rose from 27.84 to 78.43 (gain 50.59) and the CLM group's from 25.13 to 65.82 (gain 40.69). The groups did not

differ significantly at pretest (difference 2.71, $p = 0.066$), but on the post-test the FCIS group scored 12.61 points higher (95% CI 8.46 to 16.75; $t(84.0) = 6.05$, $p < 0.001$; $g = 1.29$; table 2). H_{01} was rejected.

Table 2
Tests computed from the summary statistics in table 1.

Comparison	Difference	95% CI	Statistic	*p*	Effect size
Pretest: FCIS − CLM	2.71	−0.19 to 5.61	$t(81.9) = 1.86$	0.066	$g = 0.40$
H_{01}, post-test: FCIS − CLM	12.61	8.46 to 16.75	$t(84.0) = 6.05$	< 0.001	$g = 1.29$
H_{02}, FCIS post-test: female − male	1.03	−5.10 to 7.16	$t(41.2) = 0.34$	0.736	$g = 0.10$
H_{02}, CLM post-test: female − male	−1.65	−7.66 to 4.36	$t(36.8) = -0.56$	0.581	$g = -0.17$
H_{03}, post-test: method × gender	2.68	n/a	$F(1, 82) = 0.40$	0.528	$\eta_p^2 = 0.005$

t: Welch's t-test; g: Hedges' g; F: 2 × 2 analysis of variance on post-test scores computed from the cell statistics ($MS_{\text{error}} = 95.34$); η_p^2: partial eta squared. The H_{03} difference is the female − male gap under FCIS minus the gap under CLM.

3.2. Gender and achievement

In the FCIS group, female students scored 1.03 points higher than male students on the post-test (78.92 vs 77.89) and gained slightly more (50.89 vs 50.25). In the CLM group, male students scored 1.65 points higher (66.57 vs 64.92) and gained more (41.54 vs 39.66). Neither post-test difference was significant (female–male, FCIS: $p = 0.736$, $g = 0.10$; CLM: $p = 0.581$, $g = -0.17$; table 2), so H_{02} was not rejected for either group.

3.3. Interaction of teaching method and gender

The female–male gap on the post-test was 1.03 points under FCIS and −1.65 under CLM. The difference between the two gaps, 2.68 points, was not significant ($F(1, 82) = 0.40$, $p = 0.528$, $\eta_p^2 = 0.005$). The data give no evidence that the advantage of FCIS depended on gender, and H_{03} was not rejected.

4. Discussion

Students taught Biology with FCIS scored 12.61 points higher on the post-test than those taught with CLM ($g = 1.29$), while the groups differed by only 2.71 points at pretest. This is consistent with Ogunleye et al. [13] and Nwoke, Mang and Onuoha [12], who reported better outcomes for flipped classroom students in Biology and Mathematics. A possible explanation is the pre-class phase: students who had worked through the videos, audio explanations and readings at home may have come to class better prepared for discussion and problem solving.

Gender made no detectable difference. Female students scored slightly higher than males under FCIS and males slightly higher under CLM, but neither difference nor the interaction was significant. This agrees with Abbas and Idris [1], who found no significant difference between male and female students taught genetics with the flipped classroom. The confidence intervals for the gender comparisons are wide (table 2), however, so samples of this size cannot rule out small gender differences.

The study has several limitations. Intact classes in two schools were assigned to the methods without randomisation, so differences between classes, teachers or schools may have contributed to the results. The tests were computed from summary statistics and do not adjust for the 2.71-point pretest difference. The intervention covered three topics of the SS2 Biology curriculum over six weeks, and its outcome may also have depended on how ready the Biology teachers were to use the flipped classroom.

5. Conclusion

In this sample of SS2 students in the Awka Education Zone of Anambra State, students taught Biology with FCIS scored higher on the post-test than those taught with CLM. Male and female students did not differ significantly under either method, and the interaction of teaching method and gender was not significant. Given the quasi-experimental design and the unadjusted comparison, these findings should be confirmed in more schools, with analyses that adjust for pretest scores.

6. Recommendations

Based on the findings, the following are recommended:

1. Secondary schools may consider using FCIS to teach Biology.
2. Biology teachers should be trained to prepare pre-class materials and to facilitate, rather than deliver, learning in class.
3. School authorities should provide the technological resources that students need for independent pre-class learning.
4. Policymakers and curriculum developers may consider flipped classroom principles for Biology instruction once larger studies, including studies in other subjects and settings, confirm these results.

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