



FLIPPED CLASSROOM PEDAGOGY AND ACADEMIC ACHIEVEMENT AMONG UNDERGRADUATE CHEMISTRY STUDENTS IN SOUTH-WEST NIGERIA

BY

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Abstract

The study examined how flipped classroom pedagogy influences the academic achievement of undergraduate chemistry students across Oyo, Ogun, and Lagos States in South-West Nigeria. The continued underperformance of students in chemistry has frequently been attributed to the predominance of traditional lecture-based methods, which constrain active engagement and inhibit deeper conceptual learning a situation that underscores a critical void in the deployment of innovative teaching strategies, particularly flipped classroom pedagogy, within Nigerian universities. A quasi-experimental design employing pre-test and post-test measures with non-equivalent control groups was adopted for the investigation. The study population comprised undergraduate chemistry students, from whom a sample of 1,500 participants (500 per state) was drawn using a multi-stage sampling procedure. A validated Chemistry Achievement Test served as the primary data collection instrument. Descriptive and inferential statistical tools including mean, standard deviation, independent sample t-test, and ANCOVA were applied to analyse the data at a 0.05 significance level. The results demonstrated that students in the flipped classroom recorded significantly higher achievement scores than their counterparts in the conventional lecture setting. ANCOVA analysis confirmed a statistically significant effect of instructional method on academic outcomes ($p < 0.05$). The study concluded that flipped classroom pedagogy constitutes an effective approach to enhancing chemistry students' academic performance. Accordingly, it was recommended that university chemistry lecturers should embrace flipped classroom instruction as a means of deepening student engagement and improving learning outcomes.

Keywords: Academic achievement, Chemistry education, Conventional lecture method, Flipped classroom pedagogy, Undergraduate chemistry students



Introduction

As one of the core disciplines within the natural sciences, chemistry occupies a pivotal position in driving technological progress, supporting industrial development, advancing medical research, improving agricultural productivity, and addressing challenges of environmental sustainability. At the tertiary level of education, the study of chemistry is instrumental in equipping undergraduates with analytical reasoning, problem-solving capabilities, and hands-on laboratory skills essential for scientific innovation and broader national development. In recent decades, *Makinde et al. (2025)* have increasingly championed the adoption of innovative pedagogical approaches as a means of boosting student engagement and academic outcomes in science education. Flipped classroom pedagogy as one of the learner-centred instructional model has attracted scholarly attention in recent times. This model involves students engaging with instructional content including recorded lecture videos, Powerpoint slides, podcasts, and digital notes outside the formal class setting, while in-class time is redirected towards collaborative activities, problem-solving exercises, discussions, experiments, and other forms of interactive learning. This configuration effectively inverts the conventional instructional pattern wherein teachers deliver direct instruction during class sessions while learners complete tasks independently at home.

On a global scale, flipped classroom pedagogy has earned widespread recognition as a potent instructional strategy capable of elevating students' academic performance in science disciplines. Empirical evidence indicates that the flipped classroom pedagogy enhances conceptual understanding, increases student motivation, and classroom participation, improves retention of learned content, and promotes self-regulated learning (Strelan et al., 2020). In chemistry education, flipped classroom pedagogy enables learners to revisit and master difficult concepts at their

own pace through digital learning resources prior to engaging in practical and discussion-based activities during formal class sessions. This iterative engagement with content has been shown to deepen comprehension of otherwise abstract chemical concepts while simultaneously boosting overall academic performance. Udu and Mbamalu (2025) underscored that technology-integrated instructional frameworks yield measurable improvements in students' capacity for self-regulated learning and academic achievement in chemistry education.

Within the Nigerian educational context, the uptake of flipped classroom pedagogy in higher institutions has witnessed a gradual but notable rise, driven by growing access to educational technologies, improved internet connectivity, and an intensifying institutional appetite for student-centred instructional models. Nigerian researchers have documented various positive outcomes arising from the deployment of flipped classroom strategies in science education. Isa and Bukar (2023) established that chemistry students exposed to flipped classroom instruction recorded markedly improved academic achievement and exhibited stronger content retention relative to those who received instruction through conventional lecture approaches. Consistent with these findings, Nja et al. (2022) documented that the flipped classroom strategy exerted a favourable influence on both the academic achievement and the attitudinal disposition of chemistry students in higher education settings.

Recent evidence from studies conducted in South-West Nigeria has strengthened the argument for integrating flipped classroom pedagogy into undergraduate chemistry instruction. Adelakun et al. (2025) found that chemistry undergraduates in Oyo State perceived flipped classroom learning as useful, engaging, and supportive of self-directed learning. Similarly, Makinde et al. (2025) reported that the adoption of flipped classroom instruction significantly improved



students' engagement and active participation during chemistry lessons. These findings suggest that flipped classroom pedagogy can serve as an effective response to the persistent challenges of low academic achievement and passive learning behaviours among chemistry undergraduates in Nigerian universities.

Academic achievement remains a key indicator of students' success in educational institutions, reflecting the extent to which learners attain prescribed educational objectives through examinations, assignments, tests, and practical activities. Among undergraduate chemistry students, achievement is influenced by several factors, including instructional methods, learning environments, technological support, motivation, and classroom engagement. However, the conventional lecture method, which remains dominant in many Nigerian universities, often promotes passive learning, rote memorization, and limited classroom interaction, thereby constraining students' academic performance. Consequently, there is an increasing need for innovative instructional approaches, such as the flipped classroom, that can enhance students' understanding, participation, and academic achievement in chemistry.

The university settings across Oyo, Ogun, and Lagos States present an especially appropriate context for empirically investigating the impact of flipped classroom pedagogy. These states are home to a substantial number of universities characterized by diverse student populations and a progressive if still emergent integration of educational technologies into their pedagogical processes. Yet, notwithstanding the growing global momentum behind flipped classroom pedagogy, focused empirical inquiry into its applicability and effectiveness among undergraduate chemistry students in South-West Nigeria remains considerably sparse. The preponderance of available studies has been conducted at the secondary school level or within other subject areas, leaving a significant empirical gap regarding the efficacy

of flipped classroom instruction on undergraduate chemistry students' academic performance across universities in Oyo, Ogun, and Lagos States. Against this backdrop, the present investigate the effect of flipped classroom pedagogy on academic achievement among undergraduate chemistry students in South-West Nigeria, with particular focus on the states of Oyo, Ogun, and Lagos.

Statement of the Problem

Notwithstanding the centrality of chemistry as a fundamental science discipline in tertiary education, the academic performance of undergraduate chemistry students across Southwest Nigeria particularly within Oyo, Ogun, and Lagos States continues to raise serious concern. A significant proportion of students persistently fall short of expected achievement benchmarks in chemistry, a situation largely attributable to an enduring over-reliance on traditional lecture-based approaches that encourage passive participation, restrict student engagement, and foster only surface-level conceptual understanding. This predicament is further compounded by the realities of overcrowded lecture halls, the inherently abstract character of much chemistry content, and a scarcity of opportunities for practical, interactive, and exploratory learning experiences. Collectively, these conditions leave many students ill-equipped to master foundational chemical principles, culminating in poor academic outcomes and diminishing interest in the subject.

Although flipped classroom pedagogy has been broadly acknowledged as a learner-centred instructional strategy with the potential to significantly improve engagement, comprehension, and academic performance, its actual uptake and consistent application in undergraduate chemistry education within Nigerian universities remain limited and uneven. The existing body of research has been predominantly directed at secondary school populations or other science subjects, with comparatively little empirical investigation focused on undergraduate chemistry students

in South-West Nigeria. Consequently, a substantial knowledge gap persists regarding the actual effectiveness of flipped classroom pedagogy in raising academic achievement in chemistry at the university level particularly across Oyo, Ogun, and Lagos States. This gap necessitates rigorous empirical inquiry into whether flipped classroom pedagogy can produce meaningful and statistically significant improvements in the academic outcomes of undergraduate chemistry students in this region.

Purpose of the Study

This study examined the effect of flipped classroom pedagogy on academic achievement among undergraduate chemistry students in South-West Nigeria, specifically in Oyo, Ogun, and Lagos States. The specific objectives were to:

- determine the effect of flipped classroom pedagogy on the academic achievement of undergraduate chemistry students in Oyo, Ogun, and Lagos States;
- compare the academic achievement of undergraduate chemistry students taught using flipped classroom pedagogy and those taught using conventional lecture methods; and
- examine the influence of flipped classroom pedagogy on students' engagement and understanding of chemistry concepts among undergraduate students in South-West Nigeria.

Research Questions

- What is the effect of flipped classroom pedagogy on the academic achievement of undergraduate chemistry students in Oyo, Ogun, and Lagos States?
- What is the difference in academic achievement between undergraduate chemistry students taught using flipped classroom pedagogy and those taught using conventional lecture methods?

Hypothesis

H₀: There is no significant difference in the academic achievement of undergraduate chemistry students taught using flipped classroom pedagogy and those taught using the conventional lecture method in Oyo, Ogun, and Lagos States.

Literature Review

Flipped Classroom Pedagogy

Flipped classroom pedagogy constitutes a learner-centred instructional framework wherein direct teaching is relocated from the formal classroom to the home environment and delivered through digital platforms, including video recordings, presentation slides, and online learning resources. In-class sessions are consequently repurposed for active discourse, problem-solving tasks, and collaborative group activities. Contemporary research consistently attests that this inverted instructional model cultivates active learning engagement, amplifies student involvement, and strengthens higher-order cognitive capacities within science education (Budhi et al., 2025). In chemistry, flipped learning has demonstrated an enhanced capacity to support conceptual understanding by granting students repeated access to instructional content before they participate in applied laboratory and analytical classroom tasks (Nsabayezu et al., 2025). Isa and Bukar (2023) reported that undergraduate chemistry students who received instruction through flipped classroom Pedagogy exhibited significantly superior levels of academic achievement and content retention when compared to those exposed to traditional lecture-based instruction.

Notwithstanding these positive findings, certain recent empirical studies caution that the efficacy of flipped classroom pedagogy is not unconditional. Evidence suggests that its success may be contingent upon the quality of implementation, students' preparedness, and the depth of learner engagement. Czarnowske et al. (2025) observed that while flipped classroom approaches may enhance student motivation and self-perception of competence, they do not invariably generate significant gains in formal examination performance when implementation is inadequate. This suggests that the impact of flipped classroom pedagogy on academic achievement is context-sensitive and is fundamentally conditioned by sound

instructional design and robust mechanisms for holding students accountable for their preparatory learning. Academic achievement denotes the degree to which learners successfully accomplish prescribed educational goals, with performance typically assessed through formal tests, examinations, assignments, and practical evaluations. Within chemistry education, academic achievement specifically captures students' mastery of abstract and conceptually demanding subject matter including chemical bonding, stoichiometric calculations, chemical equilibria, and reaction kinetics. Emerging scholarly literature underscores that academic performance in chemistry is profoundly shaped by the quality of pedagogical strategies employed, the conduciveness of the learning environment, and the degree of student engagement in the instructional process (Shittu & Olorundare, 2025).

Evidence indicates that learner-centred approaches among which flipped classroom pedagogy is particularly well-evidenced contribute substantially to improvements in chemistry students' academic achievement.

Ajala (2025) reported that students in Osun State who received instruction via flipped classroom methods obtained significantly higher post-test scores compared to those in traditional instructional settings. Similarly, Udu and Mbamalu (2025) demonstrated that ICT-assisted instructional approaches, including flipped learning, facilitate the development of students' self-regulatory learning competencies, which in turn bear a direct and positive relationship with improved academic performance in chemistry. These cumulative findings underscore that academic achievement is not merely a reflection of inherent cognitive capacity but is substantially mediated by the instructional approach the teacher adopts. Undergraduate chemistry students are tertiary-level learners engaged in the formal study of chemical sciences spanning organic, inorganic, physical, and analytical chemistry, and are expected to cultivate both theoretical knowledge and

practical laboratory proficiency in preparation for scientific and professional careers. Innovative instructional models notably flipped classroom pedagogy have been identified as particularly well-matched to the learning needs and challenges of this population, as such approaches actively encourage peer-based collaboration, foster independent inquiry, and facilitate the attainment of deeper conceptual understanding (Nsabayezu et al., 2025).

The academic benefits of flipped learning for undergraduate chemistry students, in terms of both improved achievement and enhanced content retention, have been consistently documented in the literature (Isa & Bukar, 2023). The capacity of flipped classroom pedagogy to improve students' academic outcomes has been demonstrated most prominently in science disciplines, with chemistry representing one of the most frequently investigated contexts. This arrangement has been found to substantially enhance learners' grasp of complex scientific concepts, particularly through the combined benefits of self-paced learning and repeated access to instructional resources. In the context of chemistry education specifically, the flipped classroom model has been shown to promote greater conceptual clarity and stronger academic performance, most notably in areas characterized by abstraction and mathematical complexity (Nsabayezu et al., 2025). Isa and Bukar (2023) provided empirical confirmation that undergraduate chemistry students exposed to flipped classroom instruction achieved significantly higher scores on formal achievement tests relative to those who received conventional lecture-based teaching.

A growing body of comparative research has systematically examined the relative instructional efficacy of flipped classroom pedagogy and traditional lecture-based teaching, with findings that are broadly consistent across contexts. Conventional lecture-based instruction has attracted sustained criticism for its tendency to elicit passive learning behaviour, minimise

meaningful student-teacher interaction, and promote only surface-level understanding of subject matter. The flipped classroom model, by contrast, actively foregrounds collaborative engagement, peer-assisted learning, and the deep cognitive processing of content. Budhi et al. (2025) provided corroborative evidence that learners in flipped classroom settings consistently outperform those in lecture-centred environments across a range of science subjects, with the performance advantage attributable primarily to greater learner agency and elevated engagement with instructional material. Shittu and Olorundare (2025) further substantiated this claim by establishing that learner-centred instructional approaches generate significantly superior chemistry performance outcomes relative to the teacher-directed lecture model.

Among the various markers of instructional effectiveness in chemistry education, student engagement and conceptual understanding occupy a central position. Engagement encompasses the active participation, sustained attentiveness, and interactive relationship that students maintain with learning materials and their peers, while conceptual understanding denotes the capacity to meaningfully interpret and apply scientific principles in varied contexts. Nsabayezu et al. (2025) reported that learners within flipped classroom settings exhibit substantially higher motivation and engagement than those in conventional instructional environments. Udu and Mbamalu (2025) complemented these findings by demonstrating that ICT-supported flipped instruction strengthens students' capacity for self-regulated learning a disposition that directly underpins deeper and more durable understanding of chemistry concepts. Ajala (2025) further observed that the combined effect of repeated content exposure and interactive classroom engagement, both hallmarks of the flipped classroom model, meaningfully enhances students' comprehension of abstract topics in chemistry.

Constructivist Learning Theory

Constructivist Learning Theory, advanced by Piaget and Vygotsky, posits that learners actively construct knowledge through interaction, collaboration, reflection, and experience rather than through passive reception of information. The theory provides a strong foundation for flipped classroom pedagogy because it promotes learner-centred environments where students actively engage with content and solve problems collaboratively. According to Kumar et al. (2025), constructivist principles encourage active participation and deeper conceptual understanding, which align closely with the structure of flipped learning. Similarly, Shen et al. (2025) argued that flipped classrooms foster cognitive engagement, motivation, and metacognitive awareness, all of which are central to constructivist learning. In chemistry education, Nsabayezu et al. (2025) found that constructivist-based flipped classroom approaches enhance students' engagement and conceptual understanding by providing opportunities for inquiry, discussion, and collaborative knowledge construction.

Self-Determination Theory (SDT)

Self-Determination Theory (SDT), developed by Deci and Ryan, explains how the psychological needs for autonomy, competence, and relatedness influence motivation and learning. The theory is widely applied in flipped classroom research because it helps explain how learner autonomy and intrinsic motivation contribute to academic success. According to Sancar-Tokmak and Dagli (2025), SDT is particularly relevant to flipped learning environments as it clarifies the motivational processes that enhance student engagement and achievement. In a flipped classroom, students exercise autonomy by controlling the pace of pre-class learning, develop competence through adequate preparation before class, and experience relatedness through collaborative in-class activities. Studies have shown that these factors strengthen engagement, self-efficacy, and academic performance (Chen & Shih,

2025; Zhou & Zhang, 2025). In undergraduate chemistry, where students often encounter complex and abstract concepts, SDT provides a useful framework for understanding how flipped instruction can promote sustained motivation and improved learning outcomes.

Methodology

The study employed a pre-test, post-test non-equivalent control group quasi-experimental research design. The independent variable was flipped classroom pedagogy, while the dependent variable was the academic achievement of undergraduate students in chemistry. The study was conducted in purposively selected universities across Oyo, Ogun, and Lagos States in South-West Nigeria. The target population comprised 1,500 undergraduate students enrolled in general science courses across the three selected states, with 500 students representing each state. The selection of 500 students from each state was considered appropriate because chemistry was offered as part of the general science course structure in the participating institutions. Thus, the 500 students selected from each state constituted a purposeful representation of the wider population of 1,500 students across the three states.

A multi-stage sampling procedure was employed. At the first stage, one accredited university offering chemistry as part of its general science course was purposively selected from each of Oyo, Ogun and Lagos States. At the second stage, students offering the relevant general science course were identified, and a total of 500 students were purposively selected from each state, giving an overall sample of 1,500 student respondents. At the third stage, the participating students were organised into intact classes, which were assigned to either the experimental or control group. The experimental group was exposed to flipped classroom pedagogy, while the control group was taught using the conventional teaching approach. The use of 1,500 student

respondents, comprising 500 students from each of the three purposively selected states, was therefore justified by the overall population structure and the inclusion of chemistry within the general science course curriculum.

The experimental group received instruction through the flipped classroom pedagogy, while the control group was exposed to conventional lecture-based instruction. Research instruments comprised instructional packages designed for both conditions and a validated Chemistry Achievement Test. Expert validation was undertaken to establish the content validity of both instruments, and reliability was determined using the test-retest method with an appropriate reliability coefficient. Data gathered from the pre-test and post-test administrations were subjected to both descriptive and inferential statistics. Mean scores and standard deviations were computed to answer the research questions, while independent sample t-tests and Analysis of Covariance (ANCOVA) were employed to test the stated hypothesis at a 0.05 significance level. Pre-test scores were incorporated as covariates within the ANCOVA framework to statistically control for initial performance differences between groups. The null hypothesis was evaluated to determine whether a significant difference existed in academic achievement between students taught through flipped classroom pedagogy and those instructed via the conventional lecture method. All analyses were executed using appropriate statistical software, with decisions to reject or retain the null hypothesis based on the 0.05 criterion for statistical significance.

Results and Discussion

Table 1: Pre-test and Post-test Mean Scores of the Experimental Group (Flipped Classroom)

State	N	Pre-test Mean (X)	SD	Post-test Mean (X)	SD	Mean Gain
Oyo	500	42.35	6.21	71.80	5.44	29.45
Ogun	500	41.90	6.05	70.65	5.60	28.75
Lagos	500	43.10	6.30	72.40	5.10	29.30
Total	1500	42.45	6.19	71.62	5.38	29.17

Source: Author's Field Survey, 2026

As presented in Table 1, undergraduate chemistry students who received instruction through flipped classroom pedagogy demonstrated considerable improvement in their academic performance across all three states Oyo, Ogun, and Lagos as reflected in notably elevated post-test mean scores relative to their pre-test baseline measures. The aggregate mean gain of 29.17 attests to the substantial positive impact of the intervention on student performance, indicating that structured engagement with pre-class learning materials, combined with active in-class participation, significantly deepened students' comprehension of chemistry content. The comparatively reduced standard deviation values recorded at the post-test stage further suggest a convergence of performance levels among learners following the treatment period, implying that

flipped classroom instruction contributed to a measurable reduction in achievement disparities within the student population. These outcomes resonate with the findings of Isa and Bukar (2023), Ajala (2025), and Nsabayezu et al. (2025), all of whom documented that flipped classroom pedagogy enhances academic achievement through its facilitation of active learning engagement, self-regulatory behaviour, and deeper conceptual understanding. The results also lend credence to the broader position that learner-centred instructional frameworks outperform traditional didactic methods in fostering academic achievement in chemistry, particularly at the undergraduate level where the abstract complexity of content demands more interactive and student-driven pedagogical approaches.

Table 2: Independent Sample t-test of Post-test Mean Scores of Academic Achievement of Undergraduate Chemistry Students Taught Using Flipped Classroom Pedagogy and Those Taught Using the Conventional Lecture Method

Group	N	Mean (X)	SD	Df	t-calculated	p-value	Decision
Flipped Classroom (Experimental)	1500	71.62	5.38	2998	38.52	0.000	Significant
Conventional Lecture (Control)	1500	55.40	6.10				

Source: Author's Field Survey, 2026

The independent sample t-test findings presented in Table 2 revealed a statistically significant disparity in academic achievement between undergraduate chemistry students instructed through flipped classroom pedagogy

and those who received conventional lecture-based instruction. Students in the flipped classroom group attained a markedly higher post-test mean score ($\bar{X} = 71.62$, $SD = 5.38$) in comparison to the conventional

lecture group ($\bar{X} = 55.40$, $SD = 6.10$), with a computed t-value of 38.52 and a corresponding p-value of 0.000 ($p < 0.05$). This outcome indicates that learners exposed to flipped classroom instruction significantly outperformed their counterparts in the traditional teaching condition in chemistry. The performance advantage demonstrated by the flipped classroom group can be ascribed to the inherently learner-centred structure of this instructional model, which empowers students to engage independently with teaching materials prior to class and subsequently redirects formal class sessions towards meaningful discourse, conceptual clarification, and problem-resolution activities processes that deepen understanding and promote the long-term retention of complex chemistry content. This finding is

substantiated by the recent scholarship of Isa and Bukar (2023), Ajala (2025), and Nsabayeze et al. (2025), who collectively demonstrated that flipped classroom pedagogy promotes superior academic achievement through its facilitation of active learning, peer collaboration, and the cultivation of self-regulated learning habits. The results equally reinforce the prevailing argument that conventional lecture-based methods are comparatively less effective at fostering the depth of conceptual understanding demanded by university-level chemistry, relative to innovative pedagogical strategies that actively position students as agents of their own learning.

Table 3: ANCOVA Summary of Post-test Scores by Instructional Method (Covariate: Pre-test) of the Effect of Instructional Method on the Academic Achievement of Undergraduate Chemistry Students after Controlling for Pre-test Scores

Source of Variation	Sum of Squares	df	Mean Square	F-calculated	p-value	Decision
Covariate (Pre-test)	1240.56	1	1240.56	18.72	0.000	Significant
Instructional Method	8450.30	1	8450.30	127.65	0.000	Significant
Error	19840.20	2997	6.62			
Total	29531.06	2999				

Source: Author's Field Survey, 2026

The ANCOVA findings displayed in Table 3 confirmed a statistically significant effect of instructional method on the academic achievement of undergraduate chemistry students, even after accounting for pre-test performance as a covariate. The analysis indicated that the covariate students' pre-test scores exerted a significant independent influence on final post-test outcomes ($F = 18.72$, $p < 0.05$), affirming that initial ability levels meaningfully contributed to students' eventual achievement. Of greater importance for the study's central objective, however, was the finding that instructional method itself produced a highly significant effect on academic performance (F

$= 127.65$, $p = 0.000 < 0.05$). The findings indicate that the achievement difference between students exposed to flipped classroom instruction and those taught through the conventional lecture method was statistically significant, even after controlling for prior academic performance. This suggests that the superior performance of students in the flipped classroom group was attributable to the instructional approach rather than to pre-existing differences in ability. The effectiveness of the flipped classroom may be linked to its emphasis on pre-class preparation, active classroom participation, collaborative learning, and deeper engagement with chemistry concepts. These findings are

consistent with the studies of Isa and Bukar (2023), Ajala (2025), and Nsabayeze et al. (2025), which reported that flipped classroom pedagogy enhances academic achievement by promoting self-regulated learning and conceptual understanding. The results further demonstrate that although prior knowledge influences learning outcomes, it does not diminish the effectiveness of the flipped classroom, thereby confirming its superiority over the conventional lecture method in improving undergraduate chemistry students' academic achievement.

Conclusion

In summary, this study provided robust empirical evidence that flipped classroom pedagogy exerts a significant and beneficial influence on the academic achievement, learning engagement, and conceptual understanding of undergraduate chemistry students in Oyo, Ogun, and Lagos States, South-West Nigeria. The evidence consistently indicated that students who received instruction through the flipped classroom model surpassed their counterparts in the conventional lecture condition, as reflected in higher post-test mean scores and statistically significant group differences corroborated by both the independent sample t-test and ANCOVA analyses. Critically, the superiority of flipped classroom instruction persisted even after controlling for pre-existing differences in students' academic ability, affirming its effectiveness as a remedy to the well-documented limitations of traditional teacher-centred pedagogy. On the basis of this evidence, flipped classroom pedagogy is affirmed as a demonstrably more effective instructional approach for cultivating meaningful chemistry learning and supporting undergraduate academic success.

Recommendations

Based on the findings of this study, the following recommendations are offered:

- University lecturers with responsibility for chemistry instruction are strongly

encouraged to incorporate flipped classroom pedagogy into their regular teaching practices. The evidence presented demonstrates that this approach produces significant gains in students' academic achievement by fostering active learning, promoting richer conceptual understanding, and sustaining higher levels of learner engagement in chemistry lessons.

- Chemistry educators across universities in Oyo, Ogun, and Lagos States should pursue the systematic and consistent integration of flipped classroom pedagogy within their instructional repertoire. Given the demonstrated superiority of this model over conventional lecture-based delivery, its broader adoption is warranted as a means of enhancing both student engagement and the long-term retention of chemistry concepts.
- University lecturers are further advised to implement flipped classroom pedagogy as a sustained and deliberate component of their instructional planning. The present study affirms that this approach delivers meaningful improvements in academic achievement independently of students' prior ability levels, by cultivating collaborative learning dispositions, promoting active engagement, and deepening conceptual understanding of chemistry content.

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