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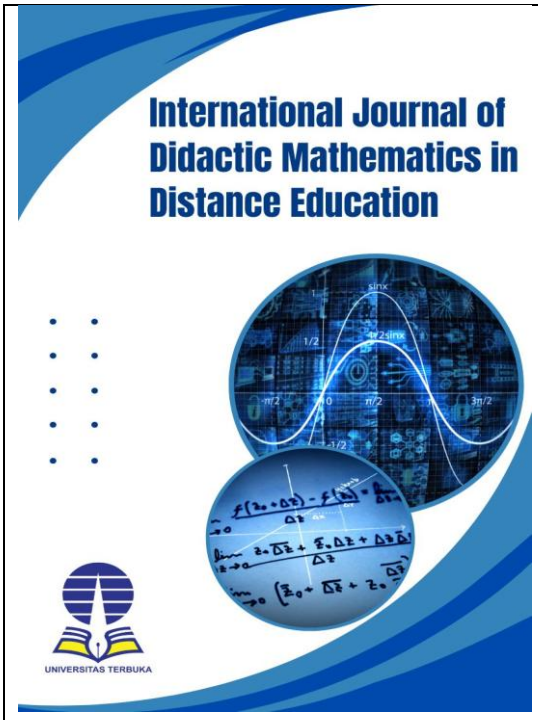

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Evaluating the impact of the flipped classroom model on senior secondary students' mathematics achievement: a quasi-experimental study in Nigeria

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Abstract
The ongoing poor achievement in mathematics underlines the need for effective instructional approaches that can boost students' comprehension and performance. The study aimed to examine the effects of the flipped classroom model and gender on the mathematics achievement of senior secondary school students in Ijebu Ode, Ogun State, Nigeria. Fifty-four students were divided into an experimental group, which received flipped classroom instruction, and a control group, which was taught through traditional methods. Data were collected over six weeks using the Mathematics Achievement Test (MAT) with a reliability coefficient of 0.74, along with pre- and post-test assessments. The data were analyzed using ANCOVA. ANCOVA results revealed that the flipped classroom model had a statistically significant effect on students' mathematics achievement ($p < 0.05$), confirming the model's impact on academic achievement. The gender analysis showed that both male and female students benefited equally from the flipped classroom model, highlighting its inclusivity as an effective teaching strategy. The study concludes that the flipped classroom model significantly improves mathematics achievement in Ogun State's secondary schools. It recommends adopting this model, coupled with appropriate teacher training and resource allocation, to promote equitable and enhanced learning outcomes.

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1. Introduction

Mathematics is a fundamental subject in education, globally recognized for its role in developing logical reasoning, problem-solving, and analytical skills. In Nigeria, mathematics is required from basic through secondary education, as abilities in mathematics strongly determines students' eligibility for higher education and employment opportunities in disciplines like engineering, technology, and economics (Asanre & Chinaka, 2024; Ogunsola et al., 2021). Mathematics education equips students with essential cognitive skills, enabling them to tackle complex problems and fostering both academic success and personal development (Agah, 2020). Additionally, Asanre et al. (2024b) argue that mathematics is often perceived as a subject reserved for science students. However, in the era of advanced digitalization, technology and science, its relevance has expanded far beyond just academia. Despite its importance, Nigerian students commonly encounter difficulty in mathematics, as evidenced by consistently low performance in both internal and external tests, such as the West African School Certificate (Abiodun et al., 2022; Maruta et al., 2022).

Academic achievement, as defined by Adeyemi (2018), refers to the successful attainment of educational goals, reflecting a student's current academic status. It shows the level of mastery a student

has obtained in connection to educational standards, giving educators and students significant insights regarding concept comprehension and learning growth (Sulaimon et al., 2023). In mathematics, evaluating academic performance is especially crucial, as it helps educators find strengths and areas requiring further support, which is essential, given the subject's foundational role in the curriculum (Asanre et al., 2022). Additionally, Asanre (2024) reported that chief examiners report indicated significant weaknesses in students' performance in mathematics, particularly in areas such as permutation and combination, mensuration, word problems, and solving simultaneous equations involving indices. These weaknesses are cause for concern and must be addressed. Ongoing poor performance in mathematics highlights the need for effective instructional strategies that can improve comprehension and close the gap between educational goals and actual outcomes (Ogunsola et al., 2021).

Traditional, teacher-centred educational models have been recognized as a factor contributing to low mathematics success. This typical technique generally entails passive learning and rote repetition, restricting students' participation and depth of knowledge (Awofala & Fatade, 2023). Consequently, there is a pressing demand for interactive, student-centred techniques that actively include students in the learning process, with a focus on boosting academic performance in mathematics. The flipped classroom model has emerged as a promising alternative to traditional teaching methods, designed to overcome their limitations by reshaping the learning process. The flipped classroom paradigm places initial learning tasks, such as watching lectures or reading materials, outside of the classroom. This technique allows students to learn at their own pace, examine tough concepts individually, and come prepared with questions (Agırman & Ercoskun, 2022).

By doing so, classroom time is repurposed for interactive, hands-on activities, such as discussions and problem-solving exercises, promoting a collaborative learning environment where students may apply theoretical knowledge with real-time support from teachers and peers (Strelan et al., 2020). This technique not only promotes engagement but has also been demonstrated to boost comprehension and academic accomplishment by allowing students to actively interact and receive instant feedback (Izadpanah, 2022; Makinde, 2020). To align with the previous researchers, this paradigm may be particularly helpful in improving mathematics achievement, as it facilitates personalized learning and builds confidence in problem-solving skills (Jensen et al., 2018; Lo & Hew, 2022). In addition to enhancing overall academic accomplishment, The flipped classroom model has shown promise in reducing gender disparities in mathematics performance by providing equal opportunities for active engagement. Gender is a well-recognized variable in education research, with studies demonstrating that male and female students often receive different degrees of encouragement, which can affect confidence and accomplishment in mathematics (Egara & Mosimege, 2023). The flipped classroom concept, however, is considered to be gender-neutral in its impact, as it stresses active involvement and individualized learning, which benefit all students regardless of gender.

By promoting a collaborative environment and allowing equitable opportunities for engagement, the flipped model can assist to eliminate traditional biases that may otherwise influence mathematics performance (Egara & Mosimege, 2023; Makinde, 2020). This study aims to evaluate the impact of the flipped classroom model on mathematics achievement among senior secondary school students, with a focus on addressing gender disparities in performance. By examining the effectiveness of this model within Nigerian schools, where traditional teaching remains predominant, the study seeks to provide insights into whether the flipped classroom can serve as an effective instructional approach to enhance mathematics achievement across genders, addressing a critical need in Nigerian mathematics education.

1.1 Statement of the Problem

Though mathematics is clearly important for secondary school, Nigerian students still show poor academic performance in the discipline. Traditional, teacher-centered teaching approaches that stress passive learning and rote memorization which do not promote the deep understanding or involvement required for success in mathematics have often blamed for underperformance (Ogunsola et al., 2021). Dealing with these issues calls for creative, student-centered methods of instruction; the flipped classroom model shows promise as such option. This approach has shown promise to increase engagement and raise

mathematics performance by moving initial material learning outside the classroom and allocating class time to interactive, problem-solving exercises (Ağırman & Ercoşkun, 2022; Strelan et al., 2020).

Although studies show that the flipped classroom concept could help to raise academic performance, empirical data particular to Nigerian secondary schools especially in Ogun State remains lacking. Studies carried out in other areas have shown increases in achievement and involvement using the flipped approach; but no study has specifically looked at how this affects the mathematics performance of senior secondary students in Ogun State. Furthermore, although some research shows that the flipped classroom paradigm might foster a more inclusive learning environment, the degree to which it solves gender disparities in mathematical performance is not widely known (Egara & Mosimege, 2023.). This highlights a substantial gap, as studying its impacts across gender lines could promote more focused and equitable educational techniques. With an eye toward gender inequalities, this study aims to close these gaps by looking at how the flipped classroom paradigm affects mathematics performance among senior secondary school students in Ogun State.

By analyzing this concept within a local context where it has yet to be empirically assessed, this study intends to give valuable insights into successful instructional practices that may boost mathematics achievement for diverse student groups in Nigeria. To achieve the objectives of this study, the following research questions.

1) What are the mean achievement scores of senior secondary students in mathematics when taught using the flipped classroom model compared to those taught using traditional methods of teaching?
2) What are the mean achievement scores of male and female secondary school students in mathematics when taught using the flipped classroom model?

1.2. Literature Review

1.2.1. Concept of Mathematics

Mathematics is a core topic in education, valued for improving students' skills in logical reasoning, problem-solving, and analytical thinking. Essential for subjects such as engineering, technology, and economics, mathematics enables students to analyze, interpret, and solve real-world problems, enabling scientific and technical growth (Agah, 2020; Igbojinwaekwu, 2019). In Nigeria, mathematics is required across educational levels, underlining its relevance in preparing students for the cognitive demands of higher education and globalised professional prospects (Oyedeji, 2016). However, the abstract character of mathematics often causes obstacles for pupils, resulting to lesser accomplishment in this subject, which has driven a search for more effective instructional methodologies (Atoyebi et al., 2023).

1.2.2. Concept of Flipped Classroom

The flipped classroom model is an instructional technique that flips regular teaching methods by distributing instructional content outside the classroom, generally through films or books. In-class time is then allocated to interactive, hands-on learning activities, where students apply their knowledge through discussions, problem-solving, and collaborative exercises (Izadpanah, 2022). This paradigm alters the teacher's function from a lecturer to a facilitator, supporting students in active engagement with the curriculum (Vanderbilt University, 2018). In mathematics education, the flipped classroom paradigm has proved success in boosting academic performance. By allowing students to learn at their own pace outside class, the model helps them to prepare and actively participate in classes, resulting to increased engagement and comprehension of mathematical ideas (Strelan et al., 2020). Research demonstrates that students in flipped classrooms frequently obtain greater academic achievements compared to those in traditional settings, benefiting from the combination of pre-class subject exposure and active, applied learning during class (Heiss & Oxley, 2021).

1.2.3. Benefits and Challenges of the Flipped Classroom

The flipped classroom technique has several benefits that can boost academic attainment. First, it stimulates more student engagement by transforming classroom time into an active learning environment, which has been demonstrated to boost understanding and performance (Lo & Hew, 2022). Additionally, it provides for flexible, self-paced learning, where students can study and absorb material individually, a method particularly effective for complicated subjects like mathematics (Jensen et al., 2018). The paradigm also promotes self-directed learning, promoting critical thinking and autonomy that are useful qualities

outside the classroom (Koh & Ahn, 2023). However, implementing the flipped classroom concept has obstacles, particularly in locations with limited access to technology. In Nigeria, many students have problems in getting dependable internet and digital gadgets, making it difficult to completely adopt this paradigm (Makinde, 2020). The flipped classroom also needs a high degree of self-discipline from students to interact with pre-class information independently, which may be challenging without motivation and help. Additionally, teachers have additional responsibilities, as they must prepare digital content and supervise interactive in-class activities, stressing the need for resources and training to properly apply this paradigm (Bawa & Baba, 2021).

1.2.4. Concept of Academic Achievement

Academic achievement refers to the level of educational attainment and proficiency a student displays in a certain subject, often measured by assessments, standardised tests, or assignments. In mathematics, academic accomplishment represents students' capacity to grasp, apply, and analyse mathematical concepts, incorporating skills such as problem-solving, calculation, and logical reasoning (Adeyemi, 2018). Sulaimon et al. (2023) emphasize that academic accomplishment offers useful insights into students' comprehension of educational standards, allowing educators to assess understanding and identify areas for development. High achievement in mathematics is extremely significant, as it is linked to success in different academic and professional sectors. Proficiency in mathematics prepares pupils for advanced studies and builds critical thinking abilities required for real-world problem-solving (Asanre et al., 2022). Persistent poor accomplishment in mathematics underlines the need for more effective instructional strategies, such as the flipped classroom model, that actively engage students and enable higher learning outcomes.

1.2.5. Concept of Gender in Education

Gender in education refers to the ways in which socially created roles and expectations influence students' experiences, performance, and engagement in topics like mathematics. Research reveals that gender stereotypes can affect how male and female students view their talents and approach learning, especially in subjects typically perceived as male-dominated, such as mathematics (Baji, 2020). These prejudices sometimes lead to variations in self-confidence, motivation, and academic success between genders, with boys often receiving greater encouragement in mathematics, which may enhance their confidence and performance relative to girls. In Nigerian educational contexts, societal and cultural expectations have been found to contribute to gender discrepancies in mathematics achievement, with female students sometimes encountering problems due to weaker confidence or reduced access to help (Musingarabwi, 2020). However, educational strategies like the flipped classroom have been demonstrated to reduce these inequities by establishing an inclusive, active learning environment. By encouraging cooperation and allowing students to interact with material at their own pace, the flipped classroom model has the potential to enhance fair outcomes in mathematics achievement for both male and female students (Egara & Mosimege, 2023).

1.3. Theoretical Framework

This study is grounded in Constructivist Learning Theory, which posits that knowledge is actively constructed by learners rather than passively absorbed. Constructivism, based on the works of theorists like Jean Piaget and Lev Vygotsky, emphasises that learning is most effective when students engage with content in an interactive, hands-on manner, building new knowledge on top of prior experiences (Xu & Shi, 2018).

In the context of the flipped classroom model, constructivist principles are directly applicable, as this model shifts the responsibility of initial content acquisition to students outside of the classroom. By studying instructional materials independently, students enter the classroom prepared to participate in collaborative, problem-solving activities, facilitating deeper learning. This approach aligns with Vygotsky's concept of the "zone of proximal development" (ZPD), where peer interaction and teacher facilitation help students build on their current understanding to achieve higher levels of learning (Pauline et al., 2021).

The flipped classroom also resonates with Social Constructivism, a branch of constructivist theory emphasising social interaction in knowledge construction. Social constructivism posits that students learn

more effectively when they work collaboratively, exchanging perspectives and refining their understanding through group interactions. The collaborative, discussion-based classroom environment in the flipped model provides ample opportunities for peer engagement, which has been shown to enhance comprehension and retention in mathematics (Strelan et al., 2020; Yildiz, 2022).

Adopting constructivist principles through the flipped classroom model is particularly justified in mathematics education, where abstract concepts benefit from active exploration and problem-solving. Studies have shown that constructivist-based approaches significantly improve students' engagement and achievement in mathematics by promoting deeper cognitive processing and critical thinking (Ugwuozor, 2020; Kutigi et al., 2022). This theoretical alignment suggests that the flipped classroom model not only supports academic achievement but also fosters an inclusive learning environment, addressing individual learning needs and encouraging equitable engagement across genders (Egara & Mosimege, 2023).

1.4. Empirical Review

Research on the flipped classroom model has showed a positive influence on students' academic ability in mathematics, with studies also showing its gender-equitable impacts. In a quasi-experimental study in Lagos, Nigeria, Makinde (2020) studied the influence of flipped classroom instruction on Senior Secondary School students' performance in mathematics. The study involved 275 students, with 147 in the flipped classroom group and 128 in a typical classroom environment. Results showed that the experimental group (flipped classroom) achieved a considerably higher mean post-test score of 30.23 compared to the control group's mean of 25.27, reflecting a gain of 5.96 points. Gender analysis found no significant differences in outcomes, suggesting that both male and female students benefited equally from the flipped classroom approach Egara and Mosimege (2023) investigated the flipped classroom's impact on students' academic progress and interest in geometry among 86 Senior Secondary School students in Nigeria. In this study, students in the flipped classroom group had a mean post-test score of 86.1 (SD = 9.9) compared to the traditional group's score of 64.7 (SD = 8.9), suggesting a considerable 25.3-point advantage in favour of the flipped approach. Additionally, interest scores jumped by 9.7 points among flipped classroom students compared to only a 0.2-point gain in the control group, emphasizing the model's capacity to encourage engagement. As with Makinde's findings, no significant gender discrepancies were identified, underscoring the flipped classroom's promise for equal outcomes.

Further corroborating these results, Eze (2023) conducted a study on trigonometry achievement among Nigeria Certificate in Education (NCE) students in Kano. The study featured 60 students, split between the flipped classroom and traditional lecture-based instruction. The flipped classroom group scored a mean of 3.34 (SD = 0.32) on post-tests compared to the control group's mean of 2.54 (SD = 0.42), suggesting a mean gain of 0.76 in favour of the flipped strategy. Interest levels were also higher in the flipped classroom, with a mean score of 28.12 against 20.53 in the traditional group. Gender study indicated no significant disparities in academic achievement, demonstrating that the flipped classroom paradigm offers balanced learning outcomes across genders.

A comprehensive meta-analysis by Shao and Liu (2021) consolidates these findings, revealing that flipped classes boost mathematics achievement across varied educational settings and student demographics. In a synthesis of 63 research including 9,163 students, their analysis found a modest impact size of 0.621 (95% CI = 0.464 - 0.778), indicating that pupils in flipped classes considerably outperformed those in traditional settings. Subgroup studies showed no consistent evidence of gender inequalities, suggesting that the flipped classroom model efficiently provides an inclusive educational environment. In summary, empirical data consistently supports the flipped classroom concept as a strategy to improve academic attainment in mathematics. This technique not only boosts achievement levels but also offers equitable learning opportunities for male and female students alike, highlighting its potential as an inclusive and effective instructional tool in mathematics education.

2. Method

2.1. Research Design

This study adopted a quasi-experimental, non-equivalent control group design to examine the impact of the flipped classroom model on students' mathematics achievement compared to traditional teaching methods. This design involved two groups: an experimental group receiving flipped classroom instruction

and a control group taught through conventional teacher-centred methods. Both groups were administered pre-tests and post-tests to assess changes in their mathematics performance. This approach allows for comparison while accounting for the fact that random assignment to groups was not feasible (Makinde, 2020; Egara & Mosimege, 2023).

2.2. Populations and samples

The research population consisted of Senior Secondary School (SSS) students within the Ijebu-Ode Local Government Area of Ogun State, Nigeria. Specifically, SSS II students were targeted for this study, as they have foundational mathematical skills and are preparing for upcoming Senior Secondary Certificate Examinations. This stage in their curriculum provided an ideal context to introduce innovative teaching methods. A purposive sampling technique was used to select two private secondary schools in the area based on criteria such as the availability of necessary technology, teacher willingness to adopt the flipped classroom model, and general accessibility. One SSS II class from each selected school was randomly assigned to either the experimental or control group. In total, 54 students participated, with 27 students in each group.

A purposive sampling technique was used to select two private secondary schools in the area. Schools were chosen based on specific criteria, such as availability of the necessary technology for the flipped classroom model, teacher willingness to adopt the model, and general accessibility. One SS II class from each selected school was then randomly assigned to either the experimental or control group, ensuring that each group was appropriately suited to the instructional methods required for this study. In total, 54 students participated, with 27 students assigned to each group.

2.3. Data Collection

Two main instruments were employed for data collection. The first was the Flipped Classroom Package (FCP), a series of instructional video lessons designed by the researcher and designed to cover key SS II mathematics topics. Each video lasted approximately 10 to 15 minutes, balancing comprehensive content delivery with an engagement-friendly length to avoid cognitive overload. Students were required to watch these videos on YouTube and complete assigned tasks, which they later discussed and expanded on during class. The second instrument, the Mathematics Achievement Test (MAT), was constructed to measure students' understanding, problem-solving abilities, and application of mathematical concepts covered in the flipped classroom lessons. The MAT consisted of 20 multiple-choice questions on topics relevant to the experiment, thereby providing an objective measure of student achievement. The instruments underwent validation by a panel that included the faculty members from departments of educational technology and mathematics and experienced mathematics teachers. This expert panel ensured that both the content and structure of the FCP and MAT were suitable for assessing student achievement in mathematics. Reliability for the MAT was established through a split-half method conducted with a sample of 22 students from outside the study group. Using the Pearson Correlation Coefficient and the Spearman-Brown prophecy formula, the MAT achieved a reliability coefficient of 0.74, indicating consistency in its ability to measure students' mathematical comprehension and skills.

2.4. Data Analysis

Data collection spanned six weeks. During the first week, mathematics teachers involved in the study were oriented on the use of the flipped classroom model, and both groups were given a pre-test to establish baseline achievement levels. Teaching commenced in weeks two through five, with the experimental group engaging in the flipped classroom activities and the control group following traditional instructional methods. In the final week, a post-test was administered to both groups to evaluate the immediate effects of the instructional methods on academic achievement in mathematics. To analyse the collected data, the study employed Analysis of Covariance (ANCOVA), which adjusted for initial differences by using pretest scores as covariates. This method provided an accurate comparison of mathematics achievement between the experimental and control groups while controlling for potential pre-existing disparities in ability. Furthermore, ANCOVA allowed for examination of any interaction effects, such as the influence of gender on the effectiveness of the flipped classroom model, thereby enabling a nuanced understanding of factors impacting student achievement in mathematics.

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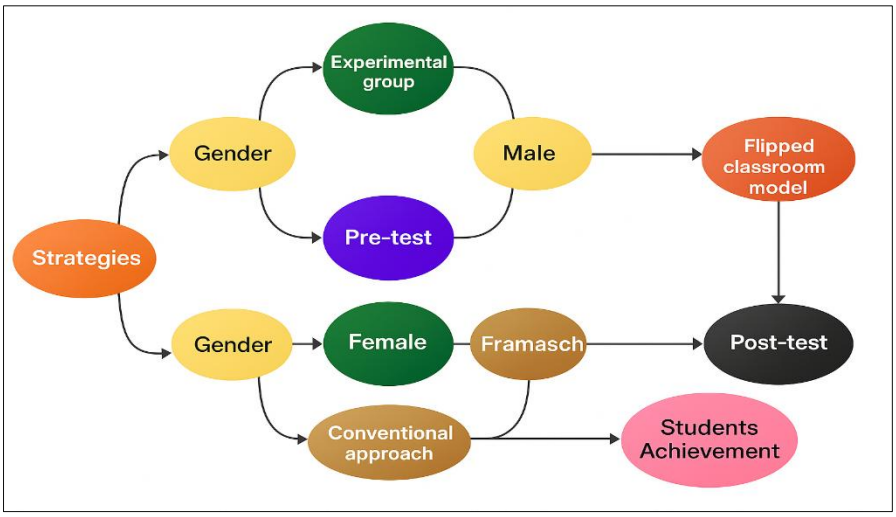
3. Results and Discussion

3.1 Results

Figure 1

Flow diagram of instructional strategies and academic achievement

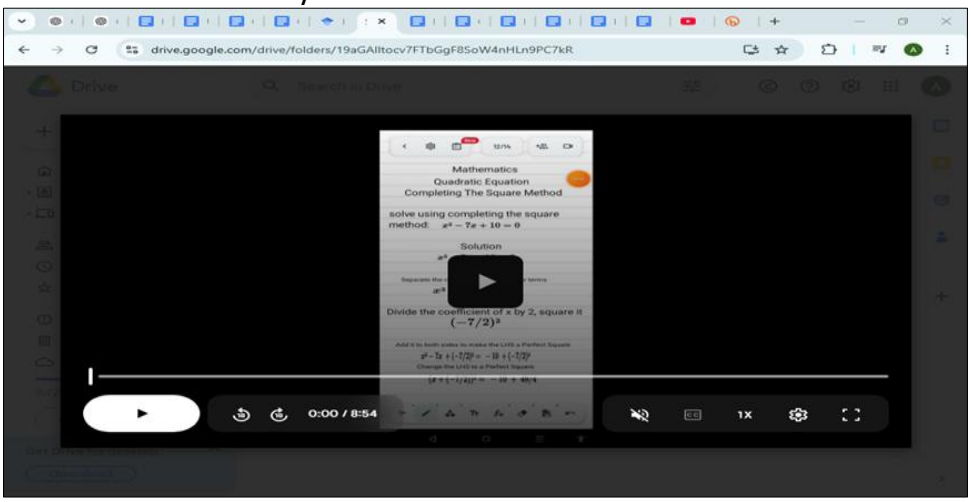


The flow diagram, which demonstrates the relationship between instructional strategies, gender, and students' academic achievement in mathematics. The framework reflects the study's quasi-experimental design and highlights the role of the flipped classroom model in improving mathematics achievement. The framework begins by dividing the participants into two groups based on the instructional strategies employed: the experimental group, exposed to the flipped classroom model, and the control group, taught using the conventional teacher-centered approach. Each group is further categorised by gender—male and female—to examine how the instructional strategies impact achievement across genders.

Both groups undergo a pre-test to establish their baseline mathematics achievement levels. Following this, the experimental group is instructed using the flipped classroom model, characterised by pre-class preparation, which involves sharing the online link with the students to study at home or at there convience, followed by interactive in-class activities, while the control group follows a traditional approach with teacher-led instruction. Below is the interphase of the online link (Figure 2).

Figure 2

Flipped Classroom Videos Screensnap



After the teaching phase, a post-test is administered to both groups to evaluate their mathematics achievement. This framework allows for a systematic comparison of the instructional strategies and their effects on students' performance, considering gender differences. The conceptual framework highlights the

flipped classroom's potential to enhance learning outcomes and promote equitable academic achievement among male and female students.

One of the main focuses of this study is to compare the mean achievement scores in mathematics between senior secondary school students taught using the flipped classroom model and those taught through traditional teaching methods. Research Question One was designed to explore the extent to which the flipped classroom approach can positively impact students' academic performance. By comparing the two groups, the study aims to reveal the effectiveness of this innovative instructional method in the context of mathematics education. The results of the data analysis are presented in Table 1, which displays the comparative achievement scores for both teaching approaches.

Table 1

Pre-test and post-test results for students' mathematics achievement

Group	N	Pre-test		Post-test		
		Mean	Std. Dev.	Mean	Std. Dev.	Mean Diff.
Control	27	12.04	1.743	13.96	1.531	1.92
Experiment	27	12.67	1.797	15.56	1.476	2.89
Total	54	12.35	1.782	14.76	1.693	

In response to the research question regarding the mean achievement scores of secondary school students in mathematics when taught using the flipped classroom model compared to traditional methods, Table 1 presents the relevant data. Students in the experimental group, who were taught using the flipped classroom model, had an average pretest score of 12.67 (SD = 1.797) and a mean posttest score of 15.56 (SD = 1.476), resulting in a mean improvement of 2.89 points. Conversely, students in the control group, taught using traditional methods, had a pretest score of 12.04 (SD = 1.743) and a mean posttest score of 13.96 (SD = 1.531), indicating a mean improvement of 1.92 points. Thus, students taught using the flipped classroom model achieved higher mean scores compared to those taught using traditional teaching methods.

The second research question seeks to examine the mean achievement scores in mathematics of male and female senior secondary school students when taught using the flipped classroom model, compared to their counterparts taught through traditional instructional methods. This question aims to investigate whether gender plays a significant role in students' academic performance under different teaching approaches. By analyzing the differences in achievement between male and female students across both instructional models, the study provides insights into the potential interaction between teaching method and gender. The findings related to this question are presented in Table 2, highlighting the comparative performance of male and female students in each teaching group.

Table 2

Achievement scores of male and female secondary school students

Gender	N	Pre-test		Post-test		
		Mean	Std. Dev.	Mean	Std. Dev.	Mean Diff.
Female	15	12.6	1.502	15.6	1.242	3
Male	12	12.75	2.179	15.5	1.784	2.75
Total	27	12.67	1.797	15.56	1.476	

In addressing the research question concerning the mean achievement scores of male and female secondary school students in mathematics when taught using the flipped classroom model, Table 2 highlights the relevant data. For students in the experimental group who were taught using the flipped classroom approach, the male students had a mean pretest score of 12.75 (SD = 2.179) and a mean posttest score of 15.5 (SD = 1.784), resulting in a mean difference of 2.75. Female students, on the other hand, had a mean pretest score of 12.6 (SD = 1.502) and a mean posttest score of 15.6 (SD = 1.242), with a mean difference of 3. The data shows that female students achieved slightly higher mean scores than their male counterparts when taught using the flipped classroom model.

Table 3
Analysis of Covariance (ANCOVA)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	50.667[a]	4	12.667	6.133	.000	.334
Intercept	142.465	1	142.465	68.978	.000	.585
Gender	2.824	1	2.824	1.367	.248	.027
Group	24.116	1	24.116	11.676	.001	.192
Gender * Group	4.741	1	4.741	2.296	.136	.045
Pretest	10.130	1	10.130	4.905	.031	.091
Error	101.203	49	2.065			
Total	11915.000	54				
Corrected Total	151.870	53				

a. R Squared = .334 (Adjusted R Squared = .279)

H_{01}: There is no significant effect of treatment on the academic achievement of Secondary School Students in Mathematics.

The analysis presented in Table 3 shows the ANCOVA results comparing the achievement scores of secondary school students taught using the flipped classroom approach (experimental group) and those taught using the conventional method (control group). The results indicate a significant effect of treatment on academic achievement, $F(1, 51) = 11.676$, $p = 0.001$. Given that the p-value (0.001) is lower than the significance threshold of $p < .05$, the null hypothesis, which states that there is no significant effect of treatment (flipped classroom) on students' academic achievement, is rejected. The findings conclude that the flipped classroom model significantly impacts the academic achievement of secondary school students. Additionally, the partial eta squared value of 0.192 suggests that 19.2% of the variance in students' achievement scores can be attributed to the flipped classroom approach.

H_{02}: There is no significant influence of gender on academic achievement of Secondary School Students in Mathematics

The analysis presented in Table 3 also displays the ANCOVA results comparing achievement scores based on gender. The results show no significant influence of gender on academic achievement, $F(1, 51) = 1.112$, $p = 0.248$. Since the p-value (0.248) is greater than the significance threshold of $p < .05$, the null hypothesis, which posits that gender does not significantly affect students' academic achievement in mathematics, is accepted. The findings suggest that gender does not have a notable impact on academic achievement. Additionally, the partial eta squared value of 0.027 indicates that 2.7% of the variance in students' achievement scores is attributable to gender.

H_{03}: There is no significant interaction effect of treatment and gender on the academic achievement of Secondary School Students

The analysis in Table 3 also presents the ANCOVA results on the interaction between treatment and gender on achievement scores of secondary school students in mathematics. The results, $F(1,49) = 2.296$, $p = 0.136$, indicate that there is no significant interaction effect between treatment and gender on students' post-test achievement scores, as the p-value (0.136) exceeds the significance threshold of $p < .05$.

3.2 Discussion

The analysis of the first research question indicates that students in the experimental group, who experienced the flipped classroom model, showed a mean improvement of 2.89 points from pretest to posttest (increasing from 12.67 to 15.56). In contrast, students in the control group, taught through traditional

methods, demonstrated a smaller mean improvement of 1.92 points (rising from 12.04 to 13.96). This difference in score gains highlights the effectiveness of the flipped classroom's active, student-centred approach, which appears to support a deeper understanding and better retention of mathematical concepts, leading to higher achievement levels overall.

Further analysis of the second research question reveals that the flipped classroom model benefits both genders effectively, with female students showing a slightly higher mean improvement in mathematics scores than male students. Specifically, female students in the flipped classroom group demonstrated a mean increase of 3 points, while male students showed an improvement of 2.75 points. This minimal difference suggests that the flipped classroom provides an inclusive learning environment, promoting equitable achievement in mathematics for both male and female students. Together, these findings underscore the potential of the flipped classroom model to improve mathematics outcomes across diverse student groups, supporting a balanced and effective approach to learning. This inclusive advantage aligns well with the study's hypotheses, which further validate the flipped classroom model's overall effectiveness in enhancing mathematics achievement.

The findings affirm the model's alignment with substantial recent research on active learning strategies. Specifically, the first hypothesis demonstrated that the flipped classroom significantly improved students' mathematics performance compared to traditional methods. Research consistently highlights the model's benefits in fostering engagement and deeper understanding. Lo and Hew (2022) and Strelan et al. (2020) discuss how the flipped classroom's structure—where students engage with materials before class and apply concepts through interactive activities during class—enhances learning outcomes. Izadpanah (2022) further underscores that pre-class preparation allows students to approach classroom activities with greater confidence and understanding, leading to more meaningful participation and improved performance in complex subjects like mathematics. Such active learning approaches help students to consolidate knowledge, fostering both immediate achievement and long-term retention of material (Heiss & Oxley, 2021).

The results from the second hypothesis reveal that the flipped classroom model benefits both male and female students equally, showing no significant differences in achievement based on gender. This is consistent with research suggesting that active learning strategies, including flipped classrooms, can neutralise traditional gender biases, creating a more inclusive environment that fosters balanced participation. Studies by Egara and Mosimege (2023) and Makinde (2020) affirm that the flipped model provides all students with equal access to resources and opportunities to engage in self-paced learning, creating a classroom dynamic that minimises the influence of gender-based stereotypes often seen in subjects like mathematics.

Lastly, the third hypothesis explored whether there was any interaction effect between treatment type (flipped classroom) and gender on mathematics achievement, with results indicating no significant interaction. Research by Shao and Liu (2021) and Jensen et al. (2018) supports this finding, indicating that the flipped classroom model's advantages are broadly applicable across diverse student demographics, including gender. Yildiz (2022) also notes that the flipped classroom model supports individualised learning paths and emphasises collaborative in-class activities, both of which foster an inclusive environment where all students can thrive regardless of background. This research underscores that the model's active, student-centred approach creates equal opportunities for students to engage with material in ways that support their personal learning needs, promoting universally positive outcomes. Overall, the study's results reinforce the flipped classroom model as an equitable and effective strategy for improving mathematics achievement across a diverse student population.

4. Conclusion

In conclusion, this study reveals that the flipped classroom model significantly boosts mathematics achievement among Senior Secondary School students in Ogun State, Nigeria. By establishing a more active, student-centred learning environment, the flipped classroom helps students to interact fully with mathematics content, reaching higher performance levels than those taught through traditional approaches. The findings imply that, within the educational setting of Ogun State, where traditional, teacher-centred approaches are often used, the introduction of flipped classroom strategies could solve

ongoing issues in mathematics attainment, specifically the use of smartphones by learners to read online help to engage them rather than playing on social media, this act help to increase the level of engagement thereby improving the cognitive level of the students in mathematics. The study also demonstrates that the flipped classroom's effects are constant across genders, supporting equitable attainment for both male and female students in Ogun State. This conclusion emphasizes the model's ability to enhance inclusive education, providing all children with an equal opportunity to flourish in mathematics. . To improve mathematics achievement in Ogun State, it is recommended that secondary schools adopt the flipped classroom model as a core instructional approach, getting the necessary tools such as quizzes, youtube, and so on to help create online lessons for the students to learn at their own pace and reduce the hectic work of the teachers. Implementing this model more broadly could address the region's challenges with low mathematics performance by fostering a more engaging and student-centred learning environment. Transitioning to the flipped classroom will require targeted professional development for mathematics teachers, focusing on creating digital content, managing interactive class sessions, and assessing student progress effectively. One of the limitation is the sample size, which was due to non avaliability of instructional materials in most schools in terms of technology avaliability and the teacher were not familiar with the approach, leading to resistance to new teaching methodss. With this research, it will help to serve as base line for furture research work in this region and globally. Since the samples are not true representation of all the secondary schools in Ogun State, Nigeria. Also, further research could explore the long-term effects of the flipped classroom model beyond immediate academic achievement in mathematics. More so, explore flipped classroom model impact across different subjects and assess how the model supports students with diverse learning needs and varying academic abilities.

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Author 1: Conceptualization, Writing - Original Draft, Editing and Visualization;
Author 2: Validation and supervision
Author 3: Writing - Review & Editing, and Methodology;

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Conflict of Interest

The authors declare no conflict of interest.
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