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Flipped Classroom Model Approach and its Impact on Mathematics Achievement among Adolescents in Education District IV of Lagos - State, Nigeria

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Abstract. The flipped classroom model has emerged as a learner-centered instructional strategy that reverses the traditional approach to teaching by shifting direct instruction outside the classroom and prioritizing active learning during class time. This study investigates the impact of the flipped classroom on students' academic achievement, critical thinking, and engagement in mathematics among adolescents. Using a descriptive survey design, data were collected from a sample of secondary school students and analyzed to determine the effectiveness of the approach. *The population for this study was drawn from three secondary schools in education district IV. A total of 210 (two hundred and ten) respondents (students) were selected for the entire study. A simple random sampling technique was employed in selecting the sample. The data for the study were collected using* titled "Impact of Flipped Classroom Model Approach on Achievement in Mathematics Questionnaire "(IFCMAAMQ). *Three null hypotheses were raised and tested at 0.05 level of significance. At the end of the data analysis.* Findings revealed that the flipped classroom significantly improved students' problem-solving skills, enhanced their participation, and fostered deeper conceptual understanding compared to conventional lecture-based methods. The model also promoted collaboration, self-regulation, and motivation, enabling learners to take greater responsibility for their learning. The study concludes that the flipped classroom is an effective pedagogical strategy for promoting higher-order thinking and improving learning outcomes in mathematics. *Based on the findings, it was recommended among other things that* educators should adopt blended learning technologies and learner-centered instructional practices to maximize the benefits of the flipped classroom model *Educators should be equipped with the necessary skills to design effective flipped lessons and moreover, workshops or informational sessions can be organized to familiarize teachers and parents with the flipped model and its benefits, ensuring a holistic and well-supported learning experience for adolescent students in mathematics.*

Keywords: Academic Achievements, Adolescents, Flipped Classroom Model, Mathematics,

1. Introduction

Education is the process of acquiring knowledge, skills, values, and understanding through various methods such as teaching, training, research and experience, this helps individuals develop intellectually, socially and emotionally preparing them for various aspects of life and contributing to personal growth and societal progress. Education is also a process of developing the cognitive, affective and psychomotor domain of an individual in order to make him acquire skills and knowledge that are relevant to him and the society where he lives. Education is continually evolving to meet the needs and expectations of learners. Advances in technology have significantly influenced teaching and learning, reshaping the way knowledge is delivered and acquired. The ultimate goal of education is to foster higher-order learning, and to achieve this, teachers are expected to design lessons that are clear, engaging, and tailored to students' abilities. Today's learners thrive more through active participation than passive listening, making it necessary for educators to create dynamic learning environments supported by modern technological tools.

In this 21st century, the shift towards learner-centered pedagogies reflects a growing demand for approaches that stimulate critical thinking, problem-solving, and

creativity. Conventional teacher-led methods are increasingly seen as inadequate for addressing these needs, particularly in mathematics. As a core subject, mathematics plays a crucial role in developing logical reasoning and analytical skills among adolescents. However, persistent underachievement in mathematics remains a major challenge across various levels of education in Nigeria, especially within Lagos State. Advancement in information and communication technologies has changed the qualifications and abilities required from people in the present information age. Due to the changes encountered in science and technology in the 21st century, also known as the information age, people are expected to be active in creating and interpreting knowledge rather than directly obtaining information presented. With the widespread use of internet, computers and mobile devices, great improvements have been achieved in accessing and producing information. Teachers have been challenged by this modern era of internet and social media by pursuing new methods to integrate online resources and techniques into their curriculum. A response to this heightened digital migration has been the flipped classroom instruction model.

The flipped classroom is an approach to teaching and learning activities where students watch a video lesson outside the class through distance learning and have hands-on activities in the class. The flipped classroom or reverse classroom is an element of blended learning, integrating both face-to-face learning in the class through group discussion and distance learning outside the class by watching a synchronous video lessons and online collaboration (Halili and Zainuddin, 2025). Blended learning can be defined as the activity of teaching and learning which combined face-to-face physical activities with online learning (Heinerichs et al., 2016). Blended learning is the combination of face-to-face and distance teaching and learning or the integration of both distance and face-to-face modalities to deliver instruction.

The flipped classroom model approach is beneficial to learning in many ways. These benefits are: reading flexibility, availability of learning materials, active learning, technological utilization pertaining to reading flexibility, students are expected to complete learning outside the classroom, these learning resources are facilitated through technological tools such as management systems and video resources. These allow students to review material before in-class and also control pace and frequency. Regarding technological utilization, teachers learn to adapt and use online instructional videos and assessment systems. Flipped classroom is also found to be advantageous because it allows active learning, which increases student engagement. Increased engagement helps students develop positive attitudes about the material (Herreid and Schiller, 2018). Instructors work more closely with students which allows for more immediate and better feedback.

Student motivation is one of the important factors that enhance learning processes using the flipped classroom approach. Motivation is defined as an internal state arouses, directs, propels and sustains behaviour. Motivation and learning are interconnected. Motivation is an inner power that rushes human to take an action or move toward a goal (Harmon-jones, 2013). Students' motivation is defined as a spirit, initiative and willingness of students to attend and learn materials. In education, motivation has been acknowledged as one of the important elements which support students' academic performance and achievement. The flipped classroom model approach helps students to manage and maintain motivation for learning mathematical concepts and enabling students to manage their own learning processes.

Student motivation is an important prerequisite for managing their learning process (Boevé et al., 2016). In the learning environment, motivation is a dimension that should be considered. Learning environments set students in motions in having adequate capabilities to reveal their own values. In recent years, it has been reported that student motivation is an important factor in terms of increasing achievement in educational environments which have been differentiated with technological developments (Deveci-Topal, 2025). Studies have concluded that web-based learning, online learning, and blended learning environments, which became part of the educational process along with technology, influence student motivation.

Mathematics is an essential part of STEM (Science, Technology, Engineering, and Mathematics) education and it has been shown to enhance the creativity of students (Lee, 2015). However, the traditional approach of teaching mathematics, where the majority of time is spent on lectures with minimal interaction between teacher and students, has not been found successful. Due to the shortcomings of this traditional approach, the flipped classroom approach has been found to improve student-teacher interaction in learning environment. Personalized interaction with teacher allows students to ask questions, seek clarification and receive immediate feedback on their understanding of mathematical concepts in flipped classroom model. This individualized attention helps to prevent misconceptions early preventing them from

becoming obstacles to learning. (Lee, 2025) found that the key to the flipped classroom is the active learning that takes place in the classroom. Engaging with teachers also provides students with the opportunity to receive guidance tailored to their learning styles and pace. Teachers can adapt their explanation and examples to suit each student's needs, making the material more accessible and comprehensible.

In the Flipped Classroom model, students take responsibility for their own learning and progress at their own speed (Davies, Dean, and Ball, 2023). Students fulfill independent and active learning by accessing the learning environments presented through the Internet whenever and wherever they want. Students' engagement with the fundamental concepts at their own pace before class enhances retention and comprehension in mathematics. The pre-class engagement with the learning materials prepares the students for in-class discussions, problem solving and collaboration activities which reinforce their understanding. This approach leads to a better grasp of mathematical concepts and better retention overtime.

In mathematics, constant practice and application are crucial for mastery. The flipped classroom model approach provides more in-class time for guided practice, application of theories and individualized support from instructors, which can contribute to improved comprehension and retention of mathematical principles. Student-teacher interaction fosters a supportive learning environment where students feel comfortable to ask questions and express their difficulties. This can boost their motivation in tackling challenging mathematical problems. Student-teacher interaction in a mathematical classroom using the flipped classroom approach contributes to better comprehension, retention and overall performance by offering personalized assistance and promoting a deeper understanding of the subject matter.

The key to the flipped classroom is the active learning that takes place in the classroom. The core idea of the flipped classroom is to flip the conventional instructional approach. The flipped classroom emphasizes the leverage of online self-regulated learning and physical classroom interaction by adopting various pedagogies, such as, inquiry-based learning, project-based learning, problem-based learning and learning by doing among collaborative team members (Cheng et al., 2019). Flipping the classroom not only enables teachers to utilize class time to teach using a variety of hands-on activities, but it also increases retention, comprehension, engagement and student-teacher interaction. Few studies have evaluated the effectiveness of classroom flipping in mathematics on student academic achievement in higher institutions. There are no rigorous studies on the effect of flipped classroom on mathematics among adolescents in secondary schools

Student learning styles and preferences should be considered in a learning environment. Instructional content and activities should align with various learning styles such as visual, auditory, or kinesthetic, this enhance engagement and understanding of difficult concepts in mathematical class. Flipped classroom model approach can accommodate these different learning styles. The reason why flipped classroom is preferred is that teacher has the chance to spend more time on classroom activities and to correct the problems with classroom activities. In this way, even in crowded classes, success can be achieved. With more class time available for interaction, teachers have the opportunity to provide individualized support, guidance and feedback to students.

Many instructors have practiced flipped teaching in their classes, whereby students watch course videos at home and finish homework in school. For example, students at home watch prerecorded video lectures from teachers, take notes, and come to class with questions prepared prior to the physical class. Class then becomes a venue for students to work through advanced concepts and learning problems. In class, teachers can spend increased time on problem solving, advanced concepts, and high-level sense-making activities. Thus, teachers have time to work individually with students in a flipped classroom (Tucker, 2012) compared with a traditional classroom, in a flipped classroom teachers have more time to provide individualized learning feedback to students.

World Health Organization (WHO) defines adolescence as a phase of life between 10-19 years of age characterized by physical growth, emotional, psychosocial and behavioural changes, thus, bringing about transformation from childhood to adulthood. These changes usually occur a year or two earlier in girls than boys. Therefore, adolescent students spur between 10 to 17years in most secondary schools in Lagos state, Nigeria.

Mathematics is a subject concerned with number, shape, change and relation. Number has to do with quantity, measurement, and scale; Shape is about configuration and arrangement; Change considers time and variation; and relation has to do with association and comparison (similarity, difference, equality). Impact is the force of one object hitting another. Subtly put, it is the strong force of impression

of one thing on another. It is also a significant or major effect of somebody or something on another. Academic achievement refers to the measurable performance outcomes of a learner in educational settings, often expressed through grades, test scores, or other forms of assessment. It reflects the extent to which a student has attained specific learning objectives, skills, and competencies within a given subject or curriculum. Academic achievement is influenced by factors such as teaching methods, learning environment, student motivation, and socio-cultural background. Mathematics achievement is a specific aspect of academic achievement that relates to a learner's performance and proficiency in mathematics. It indicates the degree to which students understand mathematical concepts, apply problem-solving strategies, and demonstrate logical reasoning in mathematical tasks. Mathematics achievement is usually assessed through standardized tests, classroom examinations, or performance-based tasks, and it serves as a key indicator of students' ability to engage with quantitative reasoning and analytical skills. According to Anaduaka and Okafor (2023), *mathematics achievement refers to the demonstrated ability of learners to understand, interpret, and apply mathematical principles, facts, and operations as assessed through tests and examinations.*

In the context of Lagos State, particularly in Education District IV, the persistent struggle of adolescents in mathematics achievement calls for pedagogical reforms that move beyond conventional practices. The flipped classroom model approach provides a potential pathway for enhancing students' academic performance by integrating technology with interactive classroom engagement. By shifting the role of the teacher from a "knowledge dispenser" to a "facilitator of learning," the model aligns with global best practices in 21st-century education. Given the increasing demand for improved mathematics outcomes in Nigeria and the need to prepare adolescents for a competitive global economy, it becomes imperative to examine how the flipped classroom approach influences mathematics achievement among learners in this region. Such an investigation will provide empirical evidence that may guide teachers, policymakers, and curriculum developers in adopting innovative practices that promote both academic success and lifelong learning skills. It is against this backdrop that this study attempts to study the impact of the flipped classroom model approach on students' academic performance in mathematics among adolescents in Education District IV of Lagos state.

1.1 Statement of the Problem

STEM (Science, Technology, Engineering, and Mathematics) program have continued to suffer from low enrolments. High failure rates in mathematical courses have haunted students, teachers, and administrators for decades.

In recent years, despite the central role of mathematics in fostering logical reasoning, problem-solving, and analytical skills, students' performance in the subject has continued to be unsatisfactory at different levels of education in Nigeria. Reports from public examinations and classroom assessments reveal that many adolescents struggle with basic mathematical concepts, leading to low achievement and negative attitudes toward the subject. This persistent trend poses a serious concern, as weak performance in mathematics limits students' academic progression and reduces their competitiveness in a technology-driven global economy. Literature had exposed that mathematics has a reputation of being difficult to teach and understand. Some factors responsible for such difficulty and understanding are itemized as follows:

- Poor method of teaching mathematics and the technical language of mathematics.
- Financial factor can affect the teaching and learning of mathematics when students are not able to afford high cost of text books for the subject.
- The learning environment itself may affect the students' interest and motivation.
- Some of the students develop phobia for mathematics which also constitutes obstacles to effective teaching and learning of mathematics.
- The use of inappropriate instructional materials and inappropriate set induction for the students at the beginning of any mathematics lesson.
- Another problem facing the effective learning of mathematics is inadequate time allocated for the delivery of the lesson content.
- In some schools, unqualified and untrained teachers handle the teaching of Mathematics which also poses a threat to learning the subject.

One major factor contributing to this problem is the continued reliance on traditional teacher-centered instructional methods, which emphasize rote memorization and passive listening. Such approaches often fail to actively engage students, address individual learning needs, or promote higher-order thinking skills. Consequently, learners experience

difficulties in applying mathematical knowledge to real-life situations, which further widens the achievement gap.

The emergence of innovative pedagogies such as the flipped classroom model presents a possible solution to these challenges. By exposing students to instructional materials outside the classroom and dedicating class time to interactive, learner-centered activities, the flipped classroom has the potential to improve understanding, engagement, and achievement in mathematics. However, despite its growing popularity globally, limited research has been conducted on its effectiveness in Nigerian secondary schools, particularly within Education District IV of Lagos State.

This gap raises a critical question: *To what extent can the flipped classroom approach improve adolescents' mathematics achievement in Lagos State?* Addressing this question is essential in determining whether the flipped classroom can serve as a viable instructional strategy to enhance mathematics learning outcomes and provide evidence-based guidance for teachers, policymakers, and curriculum planners. Hence, the task the current study set itself was, therefore, to determine the efficacy of Flipped Classroom for teaching and learning of mathematics among adolescents in secondary schools in Education District IV of Lagos State, Nigeria.

1.2 Purpose of the Study

The purpose of this study is aimed to examine Flipped classroom model approach on students' academic performances in mathematics among adolescents in Education district IV of Lagos state.

The research objectives of the study are:

- To examine the effect of the flipped classroom approach on adolescents' achievement in mathematics compared to traditional teaching methods in Education District IV of Lagos State.
- To determine whether the flipped classroom approach enhances students' engagement and active participation in learning mathematics compared to traditional methods.
- To assess the extent to which the flipped classroom approach improves adolescents' critical thinking and problem-solving skills in mathematics.

1.3 Research Hypotheses

- There is no significant impact of the flipped classroom approach on adolescents' achievement in Mathematics compared to traditional teaching methods in Education District IV of Lagos State.
- There is no Significant impact of the flipped classroom approach in enhancing students' engagement and active participation in learning mathematics compared to traditional methods.
- There is no significant impact of the flipped classroom approach in improving adolescents' critical thinking and problem-solving skills in Mathematics.

2. Research Design

This study adopted a **descriptive survey design** because it seeks to collect information from a sample of adolescents on how the **flipped classroom model** influences their **achievements in Mathematics**. The descriptive survey is appropriate here since the study intends to **describe the current situation** without manipulating variables. The researcher is interested in gathering data on students' experiences, perceptions, and performance outcomes in mathematics when taught using the flipped classroom approach.

2.1 Population of Study

The target population for this study are the Senior Secondary Two (S.S II) students from government schools in Education District IV of Lagos State. The estimated senior secondary students' population for the entire Education District II is 33,118 of which 11,827 are Senior Secondary Two (II) students (Education District IV, 2023).

2.2 Sample size and Sampling Techniques

A Simple random sampling technique was employed in selecting the sample for the study.Education district IV is made up of three zones namely Apapa, mainland and surulere. One school was selected randomly from secondary schools in each of the zones that madeup the educational district..A sample size of 210 students will be used for the purpose of the study. Seventy (70) adolescent-Students will be randomly selected from each school. Cluster sampling was employed in selection so that the teachers and students are well represented for the study.

2.3 Research Instrument

Two research instruments were used in collecting data. The first is a constructed questionnaire titled "Impact of Flipped Classroom Model Approach on Achievement in Mathematics Questionnaire

"(IFCMAAMQ) and the second instrument is a Mathematics Achievement Test (MAT), both were used for this research study.

The questionnaire contains two sections "A"and "B" while section A contained the bio-data of the selected respondents, section 'B' contained 40 items that bothered on flipped classrooms, students' engagements, active participation, critical thinking and problem- solving skills, while the second instrument was a Mathematics Achievement Test (**MAT)** prepared from WAEC/NECO (SSCE) past questions from Y (2019-2023).

2.4 Validity and Reliability of the Instrument

To ascertain the validity of the instrument, the questionnaire was given to experts in measurement and evaluation to assess its face expert and content validity and for approval before administered on the sample selected.

The pilot study was conducted on thirty (20) respondents comprised of 10 males and 10 females who did not form part of the original study. The scores at the end of the pilot study were collated and correlated using Cronbach alpha and Pearson Product Moment Correlation Coefficient to obtain the value of 0.72 for the questionnaire and 0.87 for the MAT which was used to determine the degree of relationship between the independent and dependent values as being positive and strong.

2.5 Data Analysis and Results

Table 1: Analysis of Demographic Data of respondents by frequencies and percentage

Variable	N	%
Gender		
Male	108	51.5
Female	102	48.5
Total	**210**	**100.0**
Age		
10-11 years	52	24.5
12-13 years	138	66.5
14 years and above	20	9.0
Total	**210**	**100.0**
Religion		
Christianity	175	85.5
Islamic	21	9.5
Traditional	11	4.5
Others	3	0.5
Total	**210**	**100.0**

Hypothesis One: There is no significant **impact of the flipped classroom approach on adolescents' achievement in Mathematics** compared to traditional teaching methods **in Education District IV of Lagos State**

Table 2: Relationship between Flipped classroom model approach on Adolescent Achievement in Mathematics

Variable	N	Mean	SD	df	r-cal.	p-value	Decision
Flipped Classroom model		15.07	2.996				
	200			198	.154	.012	Reject Ho1
Academic Achievement in Mathematics		17.01	3.341				

*Significant at .05 alpha level

From table 2, indicated a calculated value of r-calculated (r-cal.=.154) which is significant at p-value=.012<0.05 level of significance. Therefore, the null hypothesis which says there is no significant relationship between flipped classroom model approach and **adolescents' achievement in mathematic** compared to traditional teaching methods in Education district IV of Lagos state. of Lagos state was rejected. This implies that flipped classroom model approach significantly relate to adolescents' achievement in mathematics.

Hypothesis Two: There is no Significant impact of the **flipped classroom approach in enhancing students' engagement and active participation in learning mathematics compared to traditional methods.**

Table 3: Relationship between Flipped classroom model approach on Students' Engagement and Active Participation

Variable	N	Mean	SD	df	r-cal.	p-value	Decision
Flipped Classroom model		15.07	2.996				
	200			198	.684	.000	Reject Ho2
Students Engagement and Active Participation		16.13	2.460				

*Significant at .05 alpha level

From table 3, indicated a calculated value of r-calculated (r-cal.=.684) which is significant at p-value=.000<0.05 level of significance. Therefore, the null hypothesis which says there is no significant relationship between flipped classroom model approach and **students' engagement and active participation** towards learning mathematics in Education district IV of Lagos state. of Lagos state was rejected. This implies flipped classroom model approach significantly relates to **students' engagement and active participation** towards learning mathematics.

Hypothesis Three: There is no significant impact of **the flipped classroom approach in improving adolescents' critical thinking and problem-solving skills in Mathematics.**

Table 4: Relationship between Flipped classroom and Adolescent **critical thinking and problem-solving skills in mathematics.**

Variable	N	Mean	SD	Df	r-cal.	p-value	Decision
Engagement in Flipped Classroom	200	15.07	2.996	198	.574	.000	Reject Ho3
Adolescents Critical Thinking and Problem Solving.		15.27	2.902				

*Significant at .05 alpha level

From table 4, indicated a calculated value of r-calculated (r-cal.=.574) which is significant at p-value=.000<0.05 level of significance. Therefore, the null hypothesis which says there is no significant relationship between adolescent **critical thinking and problem-solving** in Education district IV of Lagos state was rejected. This implies that adolescent-students' engagement with pre-recorded video lessons in a flipped Classroom significantly relates to their **critical thinking and problem-solving skills of** mathematical concepts in Education district IV of Lagos state.

3. Summary of Findings

The following are the Summary of Findings of this study:

There is a significant **impact of the flipped classroom approach on adolescents' achievement in mathematics** compared to traditional teaching methods **in Education District IV of Lagos State.**
There is a significant impact of the **flipped classroom approach in enhancing students' engagement and active participation in learning mathematics compared to traditional methods.**
There is a significant impact of **the flipped classroom approach in improving adolescents' critical thinking and problem-solving skills in mathematics.**

4. Discussion of Findings

Based on the findings of this study, the researcher observed that flipped classroom model approach impact adolescent achievements in Mathematics.

Findings from hypothesis one revealed that there is a significant **impact of the flipped classroom approach on adolescents' achievement in mathematics** compared to traditional teaching methods **in Education District IV of Lagos State.** The Flipped Classroom model, where students engage with instructional content at home through pre-recorded videos and then participate in active learning activities during class, has shown notable impacts on adolescent achievements in mathematics compared to traditional teaching methods. By allowing students to review and learn foundational concepts independently, the Flipped classroom model approach fosters a more personalized and self-paced learning experience. By shifting the traditional lecture-based approach, this model empowers students to engage with instructional content independently at their own pace, fostering a sense of autonomy and ownership in the learning process. This is supporting the findings of Makinde, (2020) proved that the flipped classroom makes teaching and learning enjoyable, effective and satisfying. Studies show that flipped classroom learning has a positive impact on academic outcomes as compared to traditional learning models (Thai *et al.,* 2017).

Findings from Hypothesis two revealed that there is a significant impact of the **flipped classroom approach in enhancing students' engagement and active participation in learning mathematics compared to traditional methods.**

Thus, the Flipped classroom model approach exerts a transformative impact on adolescents' **students' engagement and active participation in learning mathematics compared to traditional methods.** This result aligns with existing literature emphasizing that flipped learning transforms the role of students from passive listeners to active participants in the learning process. According to **Bishop and Verleger (2013)**, the flipped classroom model promotes active learning by shifting direct instruction outside the classroom through videos or online resources, while

class time is devoted to interactive problem-solving and collaborative activities. This structure creates more opportunities for student-centered learning, thereby improving engagement.

Similarly, **Abeysekera and Dawson (2015)** noted that the flipped classroom design provides students with autonomy to control the pace of their initial content exposure, which fosters self-regulated learning and deeper engagement during in-class activities. In mathematics, where active practice is crucial, this engagement translates into better understanding and skill acquisition. Research by **Chen, Wang, and Chen (2014)** found that flipped classroom strategies significantly increase students' motivation and willingness to participate in mathematics lessons because they come prepared to engage in discussions, group problem-solving, and practical applications. This finding reinforces the result of the present study where students' active involvement improved markedly under the flipped classroom approach. Furthermore, **Lo and Hew (2017)** observed that in mathematics education, flipped learning not only enhances cognitive outcomes but also promotes affective gains such as increased interest, confidence, and participation. By allocating classroom time for peer learning and teacher scaffolding, students become more active contributors rather than passive recipients. In line with the present finding, **Thai, De Wever, and Valcke (2017)** reported that flipped classrooms encourage deeper interaction among learners and between students and teachers, which strengthens classroom engagement. This interactive environment is often lacking in traditional lecture-based teaching, where students tend to be passive. Therefore, the result of this study is consistent with previous empirical evidence, showing that the flipped classroom approach is effective in fostering student engagement and active participation in mathematics learning. The approach not only shifts the focus from teacher-centered to learner-centered pedagogy but also creates an environment conducive for collaboration, critical thinking, and sustained motivation.

Also, findings from hypothesis three revealed that there is a significant impact of **the flipped classroom approach in improving adolescents' critical thinking and problem-solving skills in Mathematics.** This approach often leads to deeper understanding and retention of mathematical principles, as in-class time can be dedicated to collaborative problem-solving and individualized support for critical thinking. The observed significant improvement in adolescents' critical thinking and problem-solving skills aligns with recent meta-analyses and systematic reviews showing that flipped-classroom models produce moderate gains in mathematics achievement and higher-order skills when in-class time is devoted to active problem solving (e.g., meta-analytic summaries). This effect is explained by the pedagogical logic of the FC: self-paced pre-class instruction frees classroom time for scaffolded, collaborative tasks that promote analysis and application core components of critical thinking. However, the literature also warns that effects vary with implementation quality and student access to pre-class materials; thus, successful replication requires careful design of pre-class content, structured in-class activities, and supports for students who lack resources.

5. Conclusions

The findings of this study have shown that the flipped classroom model exerts a significant positive impact on students' learning outcomes in mathematics. By shifting direct instruction outside the classroom and dedicating classroom time to active engagement, problem-solving, and collaborative learning, the model enhances students' critical thinking, participation, and overall academic performance. This approach empowers adolescents to take greater responsibility for their learning, promotes deeper conceptual understanding, and creates opportunities for meaningful teacher–student and peer interactions.

The study therefore concludes that the flipped classroom approach is a more effective instructional strategy than the traditional lecture method for improving adolescents' achievement and engagement in mathematics. Its integration into mathematics instruction not only addresses the challenges of passive learning but also prepares students with the problem-solving skills and reflective thinking abilities required in the 21st century. Teachers, curriculum developers, and policymakers are encouraged to adopt and support the flipped classroom model as a sustainable innovation for fostering academic success and lifelong learning among students.

6. Recommendations

Judging from the findings of the study the following recommendations were made:

- Educators should invest in creating high-quality and engaging pre-recorded materials. These resources should be clear, concise, and accessible to students, catering to diverse learning styles.
- Additionally, providing supplementary resources, such as interactive quizzes or practice problems, can further reinforce

understanding and allow students to self-assess their progress outside the classroom.

- Schools should encourage mathematics teachers to adopt the flipped classroom model as a complement or alternative to traditional instruction, especially for topics requiring deep conceptual understanding.
- Professional development workshops and training should be organized to equip teachers with the necessary digital literacy skills, content creation abilities, and classroom management techniques for effective implementation.
- Educational stakeholders should ensure access to reliable internet, digital devices, and user-friendly platforms to support video lectures, online learning, and interactive classroom activities.
- Curriculum planners should integrate the flipped classroom model into mathematics curricula and other subjects where active learning can significantly improve comprehension and problem-solving skills.
- Awareness and sensitization programs should be carried out for parents and students to appreciate their roles in supporting pre-class learning activities and maximizing in-class engagement.
- Teachers should incorporate formative assessments, peer evaluations, and reflective practices within the flipped model to track students' progress and provide timely feedback.

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