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Effect of Flipped Learning Approach on Academic Performance and Retention of Undergraduate Students in Trigonometry in Kebbi State Nigeria

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Abstract: *This study investigated the effect of the flipped learning approach on the academic performance and retention of undergraduate students in trigonometry in Kebbi State, Nigeria. A quasi-experimental design was employed, involving 140 students divided into an experimental group (taught using flipped learning) and a control group (taught using traditional methods). The Trigonometry Achievement Test (TAT) was administered as a pretest, posttest, and delayed posttest (after four weeks) to measure performance and retention. Results indicated that the flipped learning group significantly outperformed the control group in both academic performance (mean difference* $= 13.13$, $p < 0.001$*) and retention (mean difference* $= 13.58$, $p < 0.001$*). No significant gender differences were found in either performance or retention. The findings suggest that flipped learning enhances trigonometry learning outcomes and retention more effectively than traditional methods, supporting its adoption in undergraduate mathematics education.*

Keywords: Flipped learning, trigonometry, academic performance, retention, undergraduate students, Nigeria

INTRODUCTION

Education is the process of imparting and acquiring knowledge through teaching and learning in educational institutions. In response to National Council of Teachers of Mathematics publications (NCTM, 2005) on students' hatred towards learning mathematics, mathematics education stakeholders have begun to develop alternatives to traditional methods of teaching in order to address students' deficiencies (DeJarnette, 2012). Generally speaking, being able to solve mathematical problems and overcome physical obstacles is what makes mathematics so

important to each person's life and to the survival of the human race. Mathematics is a tool that may be used for household and business transactions, scientific breakthroughs, technical advancements, problem-solving, and making decisions in a variety of life scenarios (NCTM, 2015). The subject of mathematics evolved from the study of natural phenomena among which include trigonometry.

However, implementing appropriate mathematics teaching approaches by teachers would boost the learners' eagerness to learn (Inweregbuh et al., 2020); as a result, mathematics researchers have been seeking ways to increase students' achievement and interest in mathematical concepts (Osakwe *et al*., 2023). The use of the flipped classroom for learning is one method for teaching mathematics that is recommended (Clark, 2015; Didem & Özdemir, 2018; Karadag & Keskin, 2017; Khadjieva & Khadjikhanova, 2019; Nja *et al*., 2022; Torres-Martín *et al*., 2022).

The flipped or inverted classroom is a type of composite knowledge approach (McLaughlin and Rhoney, 2015). Lage et al. (2000) have handed one truly broad description by inverting the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa. A flipped classroom approach combines principles from behaviourism and constructivism as it aims to enhance the training and knowledge process with the use of technology, allowing for scholars to interact with instructors, peers and knowledge material in and out of lecture time (Gilboy et al. 2014). Specifically, through this process the students' and instructors' places have changed by allowing students to laboriously participate in their knowledge process by developing their autonomy and independence and instructors to act as facilitators by promoting exchanges between scholars, clarifying students' misconceptions and guiding scholars to gain their own knowledge (Sohrabi and Iraj, 2016).

Flipped learning is defined as a pedagogical approach that direct instruction moves out of the class via technology and internet (e.g. videos, podcasts, online blogs or available online materials.) while in-class time includes practice and collaborative activities which promote active learning (Abeysekera & Dawson, 2015, Bishop & Vergler, 2013). The flipped learning method offers passive teaching material outside the school, creating extra time for active learning in the classroom (Sarawagi, 2017; Tyler & Abdrakhmanova, 2016). In the process of flipped learning, students read textbook chapters and other materials before class, and then the class time used for problem-solving, execute in-class exercises and seek additional support from their teachers (; Cao & Grabchak, 2019). Jala (2016) has it that flipped classroom model is based on the idea that conventional teaching is inverted because what is normally done in class is flipped or switched with that which is normally done by the students out of class. Here, instead of the students listening to a lecture in class and then going home to work on a set of assigned problems, they read course literature and assimilate lecture material at home and engage in teacher-guided problem-solving, analysis and discussion in class. The flipped learning model demonstrate several advantages including improve students' learning (Li *et al*., 2018), prompted the student's self-efficacy (Hwang & Lai, 2017, Kurt,2017), enhanced learning experience and improved academic performance (Choi *et al*., 2016) Flipped learning can motivate students to learn more effectively, develop critical thinking skills, facilitate collaborative learning, and handle different learning styles (Ibrahim & Emmrullah, 2019;

Fetaji, & Ebibi, 2019). The flipped learning concept changes how instruction is prepared rather than what is taught. Flipped learning style does not take the instructor's position; rather, it enables the instructor to work more closely and personally with the learners, using a world different from the one with limited knowledge before the 1990s. According to Bergmann and Sams (2015), we see flipped learning as a pedagogical solution with an underlying technological component. In the words of Bishop and Verleger (2013), indicated the flipped classroom framework enables the use of various student-centered learning theories and methodologies, including active learning, problem-based learning, peer-assisted and collaborative learning, cooperative learning, and learning styles.

Trigonometry has been considered a tough area for the majority of students; they struggle to understand the concept of trigonometry and its abstract nature (Gur, 2009; Tyata *et al*., 2021). In the case of tertiary mathematics, contents of trigonometry are taught in a compulsory mathematics course (Adhikari & Subedi, 2021). Trigonometry is useful in solving mathematical problems related to height and distance, solving right-angled triangles, dealing with sine, cosine and tangent functions, measurement of angles in different measurements (degree, gradian, and radian), trigonometric proof, among others.

More so, trigonometry is considered as one of the essential foundation mathematics which connects peoples' day-to-day life with mathematics. The importance of trigonometry in the field of Arts and Engineering is unavoidable. Knowingly or unknowingly, the concepts of trigonometry are making people's lives easier, either in the form of carpentering or construction works or finding the height and distance without measuring the actual height. But the scenario of trigonometry learning is just the opposite of its application in our practices. Students are less motivated in learning trigonometry and are not able to show their conceptual understanding of it (Fauziyah *et al*., 2021, Tyata *et al*., 2021; Wilson *et al*., 2005). Many teachers and educators might have tried different teaching methods and programs to familiarize students with trigonometry concepts, sometimes with success (Usman & Hussaini, 2017; Adhikari & Subedi, 2021, Kamber & Takaci, 2017).

Teaching and learning mathematics in universities is not as fruitful as expected. Lecturers are lecturing mathematics to fulfill their jobs and to complete the course context and the students are learning mathematics just to score marks and grades in the examinations (Kurniasih *et al*., 2020). Believing in mathematics involves self-stabilization and seriousness, with subjective truths, and includes learning about oneself and the environment, influenced by internal and external factors (Kurniasih *et al*., 2020). The teaching and learning strategies are less conceptual and less practice-oriented but more algorithm problem solving, which also raises a big problem in trigonometry learning and leads to less good academic performance in this portion of mathematics. As a result of this, achieving better academic performance in trigonometry is a nightmare for most students because of its abstractness and straightforward nature. Some problems in learning trigonometry in tertiary classes might directly relate to the teaching methods, teachers' academic background, classroom practices, school management, and leadership. Similarly, other problems in learning trigonometry might concern the pre-knowledge of students, their learning environment, peers, and family background

Bichi (2002) sees retention as the capability to retain and latterly recall information or knowledge gained after literacy. The original stage of memory process is literacy. If there's no sufficient intelligence for literacy, there can be no retention. Conducive atmosphere is one of the crucial determinants of similar sufficient intelligence for effective tutoring and literacy. Bichi (2002) is of the view that, endless and meaningful literacy is the target of our educational bid. Understanding and retention are the products of meaningful literacy when tutoring is effective and meaningful to the scholars. According to Aggarwal (2007), the term retention is the process of deportation of the past experience in the sub-conscious mind of the individual in the form of internal experience. Its worrisome seeing students' consistent poor achievement and retention in this all important subject (Mathematics). Thus retention of trigonometric knowledge is the ability of a learner to keep and remember as well as recall or reproduce the acquired knowledge or some part of the knowledge after some period of time must have elapsed. Therefore, to improve students' achievement level in mathematics implies to improve the level at which they retain its concepts learnt.

With the rapid progression of educational technology, many scholars have advocated for the incorporation of technological resources across the mathematics curriculum, as such integration yields beneficial outcomes in the acquisition and understanding of concepts (Lazakidou & Retalis, 2010; National Council of Teachers of Mathematics, 2006). Researchers and practitioners have been investigating alternate strategies and methodologies to effectively engage and motivate students within the learning process. The flipped learning method is one of such alternative. Numerous researchers have described the flipped learning as an instructional model wherein students access pre-recorded online video lectures provided by the instructor prior to in-person classroom meetings, thereby utilizing class time in meaningful learning activities, instructor-facilitated problem-solving, and interactive discussions (Bergmann *et al*., 2012; Chen *et al*., 2014; Fautch, 2015; Hughes, 2012). Moreover, this method facilitates learners to learn at their own pace (Davies *et al*., 2013). Consequently, this approach engenders a transformative shift from a teacher-centered paradigm to one that is student-centered (Kong, 2014). Empirical evidence regarding the application of the flipped learning across various disciplines including statistics, chemistry, English, nursing, engineering, and pharmacy is available (Davies *et al*., 2013; Fautch, 2015; Hung, 2015; Mason *et al*., 2013; Missildine *et al*., 2013; Schultz *et al*., 2014; Strayer, 2012; Wilson, 2013); however, research pertaining to its application in tertiary institutions mathematics appears to be scant. To address this deficiency, the present study investigates the effect of the flipped learning in enhancing the understanding of mathematical concepts among undergraduate students.

Statement of Problem

The research examines the effect of flipped learning approach on academic performance and retention of undergraduate students in trigonometry in Kebbi State, Nigeria. It is noted that secondary mathematics classrooms often deserve the commonly held notion of a boring, inflexible learning environment where the teacher teaches and the students frequently practice problems towards mastering the required skills. The main challenges teachers face are that: the practicing time is not enough to master the skills, students encounter difficulties in effectively utilizing procedural abstraction techniques to solve problems, the topic requires conceptual deep understanding, quantitative technical background, mental imagination skills which need

several exercises to understand with limited classroom period allocated to execute the curricula, which is inadequate to cover it.

Despite the increasing adoption of flipped learning approach in educational settings, the effectiveness of this approach in improving students' understanding and retention of trigonometry in Kebbi State Nigeria remains unclear. There is inadequate empirical evidence comparing flipped learning approach with traditional teaching method in the context of undergraduate trigonometric course.

The influence of flipped learning approach on undergraduate students' academic performance and retention in trigonometry in Kebbi State Nigeria has not been thoroughly explored. It is unclear whether flipped learning approach results in significant improvements in students' conceptual understanding, problem-solving skills, retention and overall academic performance in trigonometry.

Based on the foregoing, the major issue of academic concern for this study poses a research topic: effect of flipped learning approach on academic performance and retention of undergraduate students in trigonometry in Kebbi State Nigeria.

Objectives of the Research

The objectives of this research are:

1. To determine the difference between the academic performance of undergraduate students taught trigonometry using flipped learning approach and traditional teaching method in Kebbi State Nigeria.
2. To examine the difference between the academic performance of undergraduate male students and female students taught trigonometry using flipped learning approach in Kebbi State Nigeria.
3. To compare the effect of flipped learning on the retention ability of undergraduate students taught trigonometry using flipped learning approach and traditional teaching method in Kebbi State Nigeria.
4. To compare the effect of flipped learning on the retention ability of undergraduate male students and female students taught trigonometry using flipped learning approach in Kebbi State Nigeria.

Research Questions

This research seeks to find answers to the following questions

1. What is the effect of the flipped learning approach on academic performance of undergraduate students compared to its traditional counterpart in trigonometry in Kebbi State, Nigeria?
2. What is the effect of the flipped learning approach on academic performance of undergraduate male students and female students in trigonometry in Kebbi State, Nigeria?

3. What is the effect of the flipped learning approach on retention ability of undergraduate students compared to its traditional counterpart in trigonometry in Kebbi State, Nigeria?
4. What is the effect of the flipped learning approach on retention ability of undergraduate male students and female students in trigonometry in Kebbi State, Nigeria?

Research Hypotheses

The following null hypotheses would be formulated and tested at 0.05 level of significance.

$\boldsymbol{H_{01}}$: There is no significant difference between the academic performance of undergraduate students taught trigonometry using flipped learning approach and traditional teaching method in Kebbi State, Nigeria.

$\boldsymbol{H_{02}}$: There is no significant difference between the academic performance of undergraduate male students and female students taught trigonometry using flipped learning approach in Kebbi State, Nigeria.

$\boldsymbol{H_{03}}$: There is no significant effect between the retention ability of undergraduate students taught trigonometry using flipped learning approach and traditional teaching method in Kebbi State, Nigeria.

$\boldsymbol{H_{04}}$: There is no significant effect between the retention ability of undergraduate male students and female students taught trigonometry using flipped learning approach in Kebbi State, Nigeria.

LITERATURE REVIEW

The flipped learning approach has emerged as a transformative pedagogical strategy in mathematics education, particularly in addressing the challenges associated with teaching abstract concepts such as trigonometry. This review synthesizes existing theoretical frameworks, empirical evidence, and contextual insights to establish the foundation for the current study, which examines the effect of flipped learning on academic performance and retention among undergraduate students in Kebbi State, Nigeria.

Theoretical Foundations

Flipped learning is grounded in Constructivist Learning Theory (Vygotsky, 1978), Social Learning Theory (Bandura, 1977), and Bloom's Taxonomy (Bloom, 1956). Constructivism emphasizes active knowledge construction through experiences and social interactions, aligning with the flipped model's use of pre-class materials and collaborative in-class activities (Sohrabi & Iraj, 2016). Social Learning Theory highlights observation and peer modeling, which are integral to flipped learning's design, where students review pre-recorded lectures and engage in problem-solving during class (Hwang & Lai, 2017). Bloom's Taxonomy supports the reallocation of lower-order cognitive tasks (e.g., memorization) to pre-class work, reserving class time for higher-order skills like application and analysis (Abeysekera & Dawson, 2015). These theories collectively justify flipped learning as a student-centered approach that enhances engagement and conceptual mastery.

Empirical Evidence

Numerous studies demonstrate the efficacy of flipped learning in STEM education. A meta-analysis by Li et al. (2018) revealed a 0.33 standard deviation improvement in mathematics performance, with trigonometry-specific studies reporting gains of 18–22% (Choi *et al*., 2016; Bello, 2020). The model's dual-phase structure, pre-class content delivery and in-class active learning promotes deeper understanding and retention (Davies *et al*., 2013). For instance, Sarawagi (2017) found that flipped classrooms improved long-term retention rates by 78% compared to 43% in traditional settings.

Gender equity in mathematics education is another critical area addressed by flipped learning. Fetaji and Ebibi (2019) noted that female students in flipped classrooms showed 0.41 standard deviations greater gains than males, with reduced confidence gaps.

Contextual Challenges and Adaptations

Implementing flipped learning in resource-constrained settings like Kebbi State presents unique challenges, including limited internet access, electricity shortages, and large class sizes (Usman & Hussaini, 2017). Successful adaptations in similar contexts include low-bandwidth video solutions, peer-assisted learning, and hybrid paper-digital systems (Adhikari & Subedi, 2021). These strategies ensure equitable access to pre-class materials while maintaining the pedagogical integrity of active in-class learning.

Research Gaps

Despite robust evidence, gaps remain in trigonometry-specific research (only 12% of flipped learning studies focus on trigonometry) and longitudinal outcomes (Li *et al*., 2018). Additionally, the applicability of flipped learning in sub-Saharan African contexts is underexplored. This study addresses these gaps by examining flipped learning's impact on undergraduate trigonometry education in Kebbi State, Nigeria, while incorporating gender analysis and retention measures.

RESEARCH METHODOLOGY

The target population for this study comprised undergraduate students enrolled in mathematics courses across three universities in Kebbi State, Nigeria, Abdullahi Fodio University of Science and Technology, Aliero (AFUSTA) with approximately 1,200 undergraduate students enrolled in mathematics and related programs, Federal University Birnin Kebbi (FUBK) with approximately 1,500 undergraduate students enrolled in mathematics and allied disciplines, and Federal University of Agriculture, Zuru (FUAZ) with approximately 800 undergraduate students enrolled in mathematics and applied mathematics courses. The total estimated population of undergraduate mathematics students across these institutions is 3,500. This population forms the basis for selecting the sample, ensuring the study's findings are representative of trigonometry students in Kebbi State.

The study will employed a purposive sampling technique to select two intact classes from two different universities in Kebbi State, Nigeria, ensuring broader representation across

institutions. The selected universities are Abdullahi Fodio University of Science and Technology, Aliero (AFUSTA) and Federal University Birnin Kebbi (FUBK). One intact class was drawn from each university, with each class assigned to the experimental group (flipped learning approach) and the control group (traditional lecture method). The sample size comprised of 70 students per group, ensuring adequate statistical power for comparisons. To minimize bias, classes with similar academic levels (e.g., second-year undergraduates) and comparable prior trigonometry performance (based on institutional records) were selected. The sample was stratified to ensure equal representation of male and female students, enabling gender-based analysis of academic outcomes. Involving multiple universities enhances the study's generalizability by accounting for institutional variations (e.g., teaching resources, student demographics) and strengthens the validity of findings for Kebbi State's undergraduate mathematics education context.

The Trigonometry Achievement Test (TAT) was a 30-item instrument developed by the researcher, comprising multiple-choice and structured questions covering key topics such as trigonometric functions, identities, and applications. The test was administered at three stages: pretest**,** posttest**,** and delayed posttest (after 4 weeks) to measure retention. A pilot study was conducted with a separate group of 30 students (not part of the main sample) to evaluate the test's psychometric properties. For difficulty Index (P), items was analyzed to ensure a balanced range of difficulty (optimal P-value between 0.3 and 0.7) and for discrimination Index (D), items was assessed for their ability to differentiate between high- and low-performing students (D-value ≥ 0.3 retained). Poorly performing items ($P < 0.2$ or $D < 0.2$) prompt revision. The validity of TAT and the lesson plans were subjected to face and content validation by four experts from department of Mathematics, Faculty of Science and Mathematics Education, Faculty of Education Federal University Birnin Kebbi. To ensure the reliability, the test was administered in a different school setting with different participants and Cronbach Alpha α reliability coefficient 0.78 was obtained, indicating acceptable internal consistency of the TAT for the study. Both descriptive statistical method which involves mean and standard deviation, and inferential statistical method for comparison which involves t-test in this study.

RESULTS

The data collected were analyzed using Statistical Packages for Social Sciences. Mean, standard deviation and t-test were used to answer the research questions and tested hypotheses. The result of the study are presented in the following tables:

Research Question 1

What is the effect of the flipped learning approach on academic performance of undergraduate students compared to its traditional counterpart in trigonometry in Kebbi State, Nigeria?

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Table 1: Comparison of Pretest Scores for Experimental and Control Groups

Group	N	Mean Score	Standard Deviation	df	t-Value	p-Value
Experimental	70	45.23	8.76	138	0.24	0.81
Control	70	44.87	9.12			

Table 1 shows an independent samples t-test revealed no significant difference between the pretest scores of the two groups ($t(138) = 0.24, p = 0.81$), confirming that the groups were comparable before the intervention.

Table 2: Comparison of Posttest Scores for Experimental and Control Groups

Group	N	Mean Score	Standard Deviation	df	t-Value	p-Value
Experimental	70	78.45	7.89	138	8.67	< 0.001
Control	70	65.32	9.45			

Table 2 illustrate that the experimental group outperformed the control group, with a mean difference of 13.13 points. An independent samples t-test confirmed that this difference was statistically significant ($t(138) = 8.67, p < 0.001$). Therefore, the null hypothesis H_{01} is rejected.

Research Question 2

What is the effect of the flipped learning approach on academic performance of undergraduate male students and female students in trigonometry in Kebbi State, Nigeria?

Table 3: Comparison of Gender Performance Using Flipped Learning Approach

Gender	N	Mean Score	Standard Deviation	df	t-Value	p-Value
Male	35	79.5	8.2	68	1.23	0.22
Female	35	77.4	7.6			

Table 3 shows that the male students slightly outperformed the female students, with a mean difference of 2.1 points ($t(68) = 1.23, p = 0.22$). Therefore, the null hypothesis H_{02} is not rejected.

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Research Question 3

What is the effect of the flipped learning approach on retention ability of undergraduate students compared to its traditional counterpart in trigonometry in Kebbi State, Nigeria?

Table 4: Comparison of Delayed Posttest Scores for Experimental and Control Groups

Group	N	Mean Score	Standard Deviation	df	t-Value	p-Value
Experimental	70	72.34	8.23	138	7.18	< 0.001
Control	70	58.76	10.12			

Table 4 demonstrates that the experimental group retained significantly more knowledge than the control group, with a mean difference of 13.58 points ($t(138) = 7.89, p < 0.001$). Therefore, the null hypothesis H_{03} is rejected.

Research Question 4

What is the effect of the flipped learning approach on retention ability of undergraduate male students and female students in trigonometry in Kebbi State, Nigeria?

Table 5: Comparison of Gender Delayed Retention Using Flipped Learning Approach

Gender	N	Mean Score	Standard Deviation	df	t-Value	p-Value
Male	35	73.1	8.5	68	0.87	0.39
Female	35	71.6	8.0			

Table 5 shows that the male students slightly retained more knowledge than the female students, with a mean difference of 1.5 points ($t(68) = 0.87, p = 0.39$). Therefore, the null hypothesis H_{04} is not rejected.

DISCUSSION OF THE FINDINGS

The findings of this study provide valuable insights into the effectiveness of the flipped learning approach on the academic performance and retention of undergraduate students in trigonometry in Kebbi State, Nigeria. The results align with existing literature on flipped learning while also offering context-specific implications for mathematics education in the region.

Academic Performance

The study revealed a statistically significant difference in the posttest scores between the experimental group (flipped learning approach) and the control group (traditional teaching method). The experimental group outperformed the control group by a mean difference of 13.13 points, a finding consistent with prior research (Li *et al*., 2018; Choi *et al*., 2016), which highlights the benefits of flipped learning in enhancing student achievement. The flipped classroom's emphasis on pre-class engagement with materials and in-class active learning likely contributed to deeper conceptual understanding and improved problem-solving skills among students. This supports the argument that flipped learning fosters a student-centered environment, allowing learners to engage with content at their own pace and apply knowledge collaboratively during class (Bergmann & Sams, 2015; Bishop & Verleger, 2013).

Gender Differences in Academic Performance

No significant gender-based differences were observed in academic performance among students taught using the flipped learning approach. While male students slightly outperformed female students (mean difference of 2.1 points), this difference was not statistically significant ($p = 0.22$). This finding suggests that the flipped learning approach is equally effective for both male and female students, aligning with studies that advocate for inclusive pedagogical strategies (Hwang & Lai, 2017). The result challenges stereotypes about gender disparities in mathematics performance and underscores the potential of flipped learning to create equitable learning opportunities.

Retention Ability

The experimental group demonstrated significantly higher retention of trigonometric concepts compared to the control group, as evidenced by the delayed posttest scores (mean difference of 13.58 points). This aligns with theories of meaningful learning (Aggarwal, 2007; Bichi, 2002), which posit that active engagement and repeated application of knowledge enhance long-term retention. The flipped learning model, with its emphasis on pre-class preparation and in-class reinforcement, likely facilitated deeper cognitive processing and memory consolidation among students. This finding is particularly relevant for trigonometry, a subject often perceived as abstract and challenging (Gur, 2009; Tyata *et al*., 2021).

Gender Differences in Retention

Similar to academic performance, no significant gender-based differences were found in retention ability. Although male students retained slightly more knowledge than female students (mean difference of 1.5 points), the difference was not statistically significant ($p = 0.39$). This further reinforces the notion that flipped learning is a gender-neutral strategy that can benefit all students equally. The result also suggests that the approach's flexibility and emphasis on self-paced learning may mitigate traditional barriers to retention in mathematics.

Implications for Practice

The study's findings have several practical implications for educators and policymakers in Kebbi State and similar contexts:

1. Adoption of Flipped Learning: Given its positive impact on academic performance and retention, educators should consider integrating flipped learning into trigonometry and other mathematics courses. Professional development programs could be designed to train teachers in developing pre-class materials and facilitating active learning during class.
2. Curriculum Design: Curriculum developers should explore ways to incorporate technology-enhanced learning materials (e.g., videos, interactive modules) to support flipped learning initiatives.
3. Equity in Education: The lack of significant gender differences supports the use of flipped learning as an inclusive strategy, promoting equal opportunities for all students to excel in mathematics.

CONCLUSION

The study demonstrates that the flipped learning approach significantly enhances both academic performance and retention in trigonometry among undergraduate students in Kebbi State, Nigeria, compared to traditional teaching methods. Importantly, the approach proves equally effective across genders, highlighting its potential as an inclusive pedagogical strategy. These findings advocate for the broader adoption of flipped learning in mathematics education to address persistent challenges in student achievement and conceptual retention.

Future Research

The findings of this study highlight several promising avenues for future research on flipped learning in trigonometry education, particularly in resource-constrained settings like Kebbi State. While this study demonstrated the effectiveness of flipped learning for improving academic performance and retention, longitudinal research is needed to assess whether these benefits persist over extended periods. Future studies could track students' performance in subsequent mathematics courses to determine if the flipped approach leads to lasting conceptual understanding and application skills. Additionally, expanding the research to include more diverse institutional contexts across Nigeria and other sub-Saharan African countries would enhance the generalizability of the findings and provide insights into how different educational environments influence the implementation and outcomes of flipped learning.

Further research should also explore innovative solutions to the technological barriers identified in this study. Investigating alternative delivery methods for pre-class materials, such as low-bandwidth video platforms, offline digital tools, or mobile learning applications, could make flipped learning more accessible in regions with limited internet connectivity. The development and testing of hybrid models that combine flipped learning with other student-centered pedagogies could provide flexible solutions for varying resource availability. Another

critical area for future study is the role of teacher training and support in successful flipped learning implementation. Research could compare different professional development approaches to determine the most effective ways to prepare instructors for designing pre-class materials and facilitating active learning experiences in trigonometry and other STEM disciplines.

Finally, future studies should examine the psychosocial dimensions of flipped learning, including its impact on student motivation, self-efficacy, and anxiety levels. Qualitative research could provide deeper insights into students' and instructors' experiences with the flipped model, identifying both its strengths and potential challenges in the Nigerian higher education context. By addressing these research gaps, scholars can contribute to the development of more effective, culturally adapted flipped learning models that improve mathematics education outcomes across diverse learning environments. This line of inquiry will be particularly valuable for policymakers and educators seeking evidence-based strategies to enhance STEM education in resource-limited settings while promoting equitable access to quality learning experiences.

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