



Effects of Flipped Peer Instruction on learning outcomes of students in integral calculus at Colleges of Education in North-West Nigeria

*¹Aliyu, A.S., ²Tsoho, M., & ²Aliyu, Z.

¹College of Agriculture and Animal Science, Division of Agricultural Colleges, Ahmadu Bello University Zaria

²Department of Science Education Ahmadu Bello University, Zaria

*Corresponding author email: abusufwan622@gmail.com

Abstract

This research investigated the impact of Flipped Peer Instruction (FPI) on the motivation, engagement, and academic performance of students in MTH 211 (Integral Calculus) within Colleges of Education in North-West Nigeria. Given the persistent challenge of low mathematics achievement in the region, a quasi-experimental design featuring a pre-test, post-test control group was implemented. The study involved 138 second-year NCE mathematics students selected from two randomly chosen colleges. The experimental group (n=72) received instruction through FPI, which utilized pre-class video lectures distributed via WhatsApp and in-class peer discussions. Conversely, the control group (n=66) was taught using conventional lecture-based methods. Data was gathered using three instruments developed and validated by the researchers: the Students' Motivation in Integral Calculus Questionnaire (SMICQ), the Students' Engagement in Integral Calculus Questionnaire (SEICQ), and the Students' Performance Test in Integral Calculus (SPTIC). Independent samples t-test analysis demonstrated statistically significant differences ($p < 0.05$) favoring the FPI group across all measured variables: performance ($M = 82.11$ vs. 47.27), motivation ($M = 60.38$ vs. 24.61), and engagement ($M = 55.78$ vs. 34.51). These findings confirm that FPI is an effective pedagogical strategy for improving both cognitive and affective learning outcomes in mathematics. The results are theoretically supported by principles of social constructivism and self-determination theory. The study concludes that FPI presents a practical and cost-effective instructional alternative for resource-constrained educational settings and strongly recommends its formal integration into teacher education curricula and national policy reforms.

Keywords: Flipped Peer Instruction, Integral Calculus, Mathematics Education, Motivation, Engagement

Introduction

Mathematics remains a foundational subject in teacher education across the globe, playing a critical role in shaping logical reasoning, analytical skills, and scientific literacy. In Nigerian colleges of education, the Mathematics 211 (MTH 211) course typically offered in the second semester focuses on integral calculus, sequences and series, and an introduction to multivariable concepts, aligning with the standards set by the National Commission for Colleges of Education (NCCE, 2012). These topics are crucial in preparing pre-service teachers for effective mathematics instruction at the secondary level. However, mathematics education in Nigeria, particularly in the North-West region, faces considerable challenges. Studies show persistently low performance in mathematics across many levels of education. According to the National Bureau of Statistics and the Universal Basic Education Commission (UBEC), fewer than 55% of Nigerian students meet basic numeracy standards, with the situation more acute in the North-West due to factors such as under-resourced schools, large class sizes, and a lack of qualified mathematics teachers (UBEC, 2020; Adeleke, 2018). This instructional gap often leads to student disengagement, low motivation, and high failure rates in national assessments such as the West African Senior School Certificate Examination (WASSCE), where failure rates have exceeded 60% in some years in the region (WAEC, 2020).

The quality of instruction plays a pivotal role in these outcomes. Conventional, teacher-centered methods, primarily relying on lectures, remain dominant, often rendering student's passive and disconnected from the learning process. Rote memorization, lack of hands-on activities, and minimal use of teaching aids further limit student engagement (Ibrahim & Adamu, 2019). Moreover, many instructors in colleges lack training in modern pedagogical techniques, resulting in limited exposure to active or student-centered learning strategies (Omebe &

Eze, 2020) such as flipped classroom. In response to these systemic challenges, innovative pedagogical approaches like Flipped Peer Instruction (FPI) have gained international recognition. Bishop and Verleger (2013) in their meta-analysis defines the flipped classroom and outlines best practices, stressing that the combination of video lectures and active in-class learning is more effective than either alone. The flipped classroom reverses the conventional lecture-homework model by delivering instructional content (typically via videos or readings) outside the classroom, freeing up in-class time for active learning, problem-solving, and collaborative tasks (Bergmann & Sams, 2012; Eberly Center, Carnegie Mellon University, 2021). Rooted in constructivist theory, the flipped model allows students to learn at their own pace and use class time for deeper understanding through teacher guidance and peer interaction (Zainuddin & Halili, 2016). In view of Vygotsky's Social Constructivism: Emphasizes learning as a socially mediated activity. FPI supports this by shifting content acquisition to the individual level and conceptual refinement to the social classroom space (Vygotsky, 1978). This theoretical framework supports the finding that engagement and performance improve when students collaborate with peers during conceptual learning. In the context of Nigerian teacher education, this aligns with the need to shift from teacher-centered instruction to socially interactive learning environments.

Peer Instruction (PI), introduced by Mazur (1997), complements the flipped model by integrating conceptual questioning and peer discussion into the learning process. After being introduced to content, students engage in structured discussions where they defend and refine their understanding with peers. This dual structure has been shown to enhance conceptual clarity, engagement, and self-confidence, especially in STEM disciplines (Crouch & Mazur, 2001; Lasry et al., 2008). Chao et al. (2015) demonstrated that peer instruction integrated into flipped settings improves performance and engagement more than traditional peer teaching. This supports the inclusion of peer-led discussions after video-based instruction. The findings that motivation and engagement were significantly higher in the experimental group can be explained by this collaborative knowledge construction, which also improves students' communication and leadership skills essential for future teachers.

Empirical evidence supports the effectiveness of FPI in improving student motivation, engagement, and academic performance. For instance, Egara and Mosimege (2023) demonstrated that Nigerian secondary students exposed to flipped classroom techniques showed higher interest and achievement in geometry than those taught via traditional methods. Similarly, Eltahir and Alsalhi (2025) found that university students in flipped courses outperformed their peers in traditional settings, reporting greater motivation and deeper learning. These effects are particularly pronounced when PI is used within flipped classrooms, creating a dynamic, socially interactive learning environment (Zainuddin, 2017; Awidi & Paynter, 2019). Despite these promising findings, implementing FPI in Nigerian teacher education programs faces infrastructural and pedagogical barriers. Many colleges of education lack reliable internet access, digital devices, or ICT-trained personnel to facilitate technology-enhanced learning (NCCE, 2021). Nonetheless, national policy is increasingly supportive of innovation. The Nigerian National Policy on Education (FRN, 2013) and the revised NCCE minimum standards emphasize the integration of ICT and learner-centered pedagogies in teacher preparation. Programs like the UBEC professional development initiative for North-West educators also highlight the growing institutional commitment to reforming instructional practices (UBEC, 2020). Thus, investigating the effect of Flipped Peer Instruction on motivation, engagement, and performance in MTH 211 among Colleges of Education Students (NCE) in North-West Nigeria is both timely and critical. This study explores whether adopting this active-learning pedagogy can improve cognitive and affective outcomes in a region where mathematics achievement has historically been low, and instructional innovation is urgently needed.

Aim and Objectives of the Study

The aim of the study was to investigate the impact of Flipped Peer Instruction (FPI) on the motivation, engagement, and academic performance of students in MTH 211 (Integral Calculus) within Colleges of Education in North-West Nigeria. The following are the specific objectives of the study:

1. Find out the effect of Flipped Peer Instruction on performance in MTH 211 among NCE mathematics students in North-West Nigeria
2. Determine the effect of Flipped Peer Instruction (FPI) on motivation in MTH 211 among NCE mathematics students in North-West Nigeria
3. Examine the effect of Flipped Peer Instruction on engagement in MTH 211 among NCE mathematics students in North-West Nigeria

Null Hypotheses

The researcher formulates the following Null Hypotheses to be tested at $P \leq 0.05$ level of significance:

H₀₁: There is no significance difference between the performance of students in integral calculus taught using FPI and those taught using conventional method

H₀: There is no significance difference between the motivation of students in integral calculus taught using FPI and those taught using conventional method

H₀₃: There is no significance difference between the engagement of students in integral calculus taught using FPI and those taught using conventional method

Methods and Materials

The researchers used a quasi-experimental design involving experimental and control groups with post-test measures. A sample of 138 N.C.E two students from two colleges of education in the North-West Nigeria were sampled from fourteen colleges of education using simple random sampling technique. The two colleges were assigned to be experimental and control groups. The experimental group with 72 students was taught using Flipped Peer Instruction (FPI), while the control group with 66 students was taught using traditional lecture method. The experimental group was taught for twelve weeks using the combined instructions that are; flipped and peer instructions. A WhatsApp platform was created by the lecturer in collaboration with class reps of the various combinations and register all the students that are taking the course. The videos of lectures done by the lecturer were uploaded on the platform for the students to download and watch the lecture before coming to the class. By coming to the class, the lecturer introduced the lecture by ensuring that everyone has watched the video followed by asking conceptual questions and allowing peer discussion into the learning process. The lecturer entertained all kinds of questions that students were asking for more explanation based on the video been uploaded. The lecture was evaluated by giving a short test or an assignment. The students' Engagement, Motivation and Performance in integral calculus (MTH 211) were measured using a Students' Motivation in Integral Calculus Questionnaire (SMICQ), Students' Engagement in Integral Calculus Questionnaire (SEICQ) and Students' Performance Test in Integral Calculus (SPTIC). The three instruments SMICQ, SEICQ and SPTIC were constructed by the researchers. SMICQ and SEICQ consist of students' bio data in section A and fifteen items in form of likert scale of strongly agree (SA), Agree (A), strongly Disagree (SD) and Disagree (D) on students' Motivation in Integral Calculus and Students' Engagement in Integral Calculus in section B and C. SPTIC consists of thirty objectives questions from integral calculus with options A-D with one correct answer and three distractors in section D. The three instruments were validated by some professors in our department (Science Education A.B.U Zaria). Their correction and observations were affected as suggested by them. The instruments were pilot tested using test-retest method. The results of the pilot testing were used to determine the reliability coefficient of the instruments. The coefficients of SMICQ and SEICQ were determined using Cronbach-Alpha method and found their coefficient to be 0.95 and 0.87. For SPTIC the reliability coefficient was determined using Pearson Product Moment Coefficient (PPMC) and found the coefficient to be 0.93. This indicated that all the instruments were reliable. The three instruments were administered to the students as post-test. The data collected were normally distributed and the groups were independent of each other's, and the data collected were analyzed using independent t-test. The results of the analysis were presented in tables as follows:

Results

H₀₁: There is no significance difference between the performance of students in integral calculus taught using FPI and those taught using conventional methods

Table 1: Summary of independent t-test analysis of student's Performance taught using Flipped Peer Instruction (FPI) and those taught using Conventional Method

Groups	N	Mean	SD	t_{cal}	Df	p-value	Decision
Experimental	72	82.11	8.51	22.23	136	0.00	Rejected
Control	66	47.27	9.89				

Significant at $p < 0.05$ level

Table 1 revealed the analysis of independent t-test with t_{cal} values of 22.23 and p-value of 0.00 at df of 136. The p-value of $0.00 < 0.05$. Based on this outcome we rejected the null hypothesis and concluded that there is significant difference between the performance of students taught using FPI and those taught using conventional

methods. This show that, the treatment giving to the experimental group using FPI significantly improved the performance of students in Integral Calculus among NCE students in North-West Nigeria.

HO₂: There is no significance difference between the motivation of students in integral calculus taught using FPI and those taught using conventional method

Table 2: Summary of independent t-test analysis of student's Motivation taught using Flipped Peer Instruction (FPI) and those taught using Conventional Method

Groups	N	Mean	SD	t_{cal}	Df	p-value	Decision
Experimental	72	60.38	8.33	32.88	136	0.00	Rejected
Control	66	24.61	3.06				

Significant at $p < 0.05$ level

Table 2 revealed the analysis of independent t-test with t_{cal} values of 32.88 and p-value of 0.00 at df of 136. The p-value of $0.00 < 0.05$ alpha value. Based on this outcome we rejected the null hypothesis and concluded that there is significant difference between the motivation of students taught using FPI and those taught using conventional methods. This show that, the treatment giving to the experimental group using FPI significantly improved the motivational level of students in Integral Calculus among NCE students in North-West Nigeria.

HO₃: There is no significance difference between the engagement of students in integral calculus taught using FPI and those taught using conventional methods

Table 3: Summary of independent t-test analysis of student's Engagement taught using Flipped Peer Instruction (FPI) and those taught using Conventional Method

Groups	N	Mean	SD	t_{cal}	Df	p-value	Decision
Experimental	72	55.78	5.92	19.41	136	0.00	Rejected
Control	66	34.51	6.94				

Significant at $p < 0.05$ level

Table 3 presents the summary of independent t-test analysis on students' engagement in Integral Calculus among NCE students in North-West Nigeria. The output of the analysis shows t-value of 19.41 and the p-value of 0.00 at df of 136. This indicated that P-value is less than the alpha value ($0.00 < 0.05$). This indicated that there was a significant difference between the students' engagement in Integral Calculus in the experimental and the control groups. Therefore, the null hypothesis that said there is no significant difference between the engagement of students in MTH 211 taught using FPI and those taught using conventional methods was rejected.

Discussion

The analysis of the collected data strongly supports the effectiveness of FPI. The result presented in Table 1 indicates a statistically significant improvement in the academic performance of students instructed using Flipped Peer Instruction compared to those taught via traditional methods (Mean = 82.11 vs. 47.27; $p < 0.05$). This finding is consistent with the growing body of academic literature that highlights the ability of FPI to enhance the comprehension and retention of mathematical concepts. This result supports Egara and Mosimege (2023), who found similar outcomes in secondary geometry, and Eltahir and Alsahhi (2025), who reported improved achievement in higher education contexts. The mechanism driving this improvement is rooted in the constructivist nature of FPI: students first engage with learning materials independently and then solidify their understanding through collaborative in-class activities. Furthermore, these findings are consistent with Wang et al. (2018), who observed substantial gains in mathematics and science performance when flipped strategies were combined with structured peer engagement. This consistent pattern suggests that flipping the classroom, particularly when integrated with structured peer learning, effectively bridges the gap between passive information reception and active problem-solving.

Table 2 demonstrates that FPI significantly enhanced students' motivation (Mean = 60.38 vs. 24.61; $p < 0.05$), confirming the model's potential to stimulate students' intrinsic interest in learning calculus. This result is strongly supported by Self-Determination Theory (SDT), proposed by Deci and Ryan (1985), which posits that learning environments that foster autonomy, competence, and relatedness are crucial for boosting motivation. The FPI model, by offering flexible, self-paced pre-class learning and cultivating supportive peer dialogue, successfully

addresses these fundamental psychological needs. Similarly, Zainuddin and Halili (2016) found that flipped classrooms are more motivating than lecture-based methods due to increased interaction, student control over the learning pace, and immediate feedback during class. In the Nigerian context, where motivation is often challenged by inadequate infrastructure and ineffective pedagogy (Ibrahim & Adamu, 2019), this study provides evidence that even simple technological interventions, such as WhatsApp-based video delivery, can substantially boost learner enthusiasm when paired with an interactive in-class structure.

Table 3 reveals a statistically significant increase in engagement among students in the FPI group (Mean = 55.78 vs. 34.51; $p < 0.05$). Engagement is a multifaceted construct encompassing behavioral, emotional, and cognitive dimensions, and the study's findings suggest that FPI stimulates all three. This result echoes the findings of Awidi and Paynter (2019), and Zainuddin (2017), who reported that implementing a flipped classroom with peer instruction leads to increased participation, attentiveness, and emotional involvement. In-class peer discussion is particularly effective in increasing engagement by providing immediate opportunities for clarification, collaborative problem-solving, and fostering student ownership of the learning process.

Conclusion

The study strongly contributes to the evidence supporting FPI as an effective instructional strategy for improving performance, motivation, and engagement in mathematics education in Nigeria. It also demonstrates the feasibility of using low-tech solutions like WhatsApp for implementing flipped learning, especially in resource-constrained environments. The statistically significant results from all three hypotheses indicate that FPI holds promise for tackling long-standing educational challenges in the region, particularly in addressing disinterest and underperformance in mathematics. The methodology, especially the use of validated instruments and a clear experimental design, enhances the reliability of the findings.

Recommendations

Based on the findings and supporting literature, here are actionable recommendations:

For Colleges of Education and Policy Makers in Education

1. Institutionalize FPI: Colleges of Education in Nigeria, especially in underserved regions, should adopt Flipped Peer Instruction as a formal part of teaching methodology, particularly in mathematics and other STEM subjects.
2. Update NCCE Curriculum: The National Commission for Colleges of Education (NCCE) should revise teacher education standards to include blended and flipped classroom strategies as core instructional models.
3. Digital Infrastructure Investment: Provide basic digital tools (e.g., smartphones, projectors, offline video libraries) and expand internet access to support mobile-based learning platforms like WhatsApp or Telegram.

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