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# Improving Attitudes Towards Calculus through Inquiry-Driven Collaborative Learning Model + ChatGPT among Preservice Mathematics Teachers: A Quasi-Experimental Study

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## Abstract

This study investigated the effect of Inquiry-Driven Collaborative Learning enriched with ChatGPT (IDCL+ChatGPT) on pre-service teachers' attitudes toward calculus in Kaduna State, Nigeria. Anchored on Social Cognitive Theory, the study adopted a quasi-experimental pretest-posttest non-equivalent control group design. The population comprised 1,122 NCE II Mathematics students in public NCE-awarding institutions in Kaduna State, from which 133 students were selected. Participants were assigned to IDCL+ChatGPT ($n = 53$), IDCL-only ($n = 45$), and conventional teaching ($n = 35$) groups. Data were collected using the Calculus Attitude Questionnaire (CAQ), validated by experts, with a reliability coefficient of 0.811. Descriptive statistics addressed the research questions, while ANCOVA and Bonferroni post hoc tests tested hypotheses at the 0.05 significance level. Results revealed a significant group effect on posttest attitude scores, $F(2,129) = 27.630$, $p < .001$, partial $\eta^2 = .300$. Bonferroni comparisons showed that IDCL+ChatGPT significantly outperformed conventional teaching ($p < .001$), while IDCL-only also significantly outperformed conventional teaching ($p < .001$). However, the difference between IDCL+ChatGPT and IDCL-only was not significant ($p = .071$). The study concludes that IDCL effectively fosters positive attitudes toward calculus, while ChatGPT provides additional instructional support that enriches students' learning experiences and supports meaningful classroom interaction and engagement.

**Keywords:** IDCL, IDCL+ChatGPT, attitude, calculus, artificial intelligence, mathematics education, social cognitive theory, NCE Students.

## 1 Introduction

Mathematics is widely recognized as the foundation of scientific advancement, technological innovation, and national development. Among the various branches of mathematics, calculus occupies a central position because it provides the conceptual framework for understanding change, motion, optimization, and numerous real-world phenomena. Consequently, calculus forms an essential component of mathematics teacher education programmes in Nigeria and serves as a prerequisite for advanced studies in science, technology, engineering, and mathematics (STEM). Despite its importance, calculus remains one of the most challenging subjects for many students. Research has consistently shown that students experience difficulties understanding abstract concepts such as limits, continuity, differentiation, and integration, resulting in poor achievement and negative attitudes toward mathematics (Dereje, 2023; Svensson & Holmqvist, 2021). Traditional lecture-based instructional approaches, which emphasize passive learning and procedural memorization, have often failed to promote conceptual understanding and positive attitudes toward learning calculus. Students' attitude toward mathematics is a critical determinant of academic success. Attitude encompasses learners' beliefs, perceptions, feelings, and behavioural tendencies toward mathematics and influences their willingness to engage in mathematical activities. Positive attitudes are associated with increased motivation, confidence, persistence, and achievement, whereas negative attitudes often lead to mathematics anxiety, avoidance behaviour, and poor academic outcomes (Sichangi, 2024).

To address these challenges, mathematics educators have increasingly advocated for learner-centred instructional approaches capable of promoting meaningful learning experiences. One of such approach is Inquiry-Based Learning (IBL) is a student-centred instructional approach that actively engages learners in constructing knowledge through questioning, investigation, collaboration, and reflection rather than passively receiving information from the teacher. Over the years, several models of IBL have been developed to guide the implementation of inquiry in classroom settings. These include the 5E Instructional Model (Bybee et al., 2006), the Inquiry Cycle (Pedaste et al., 2015), and the Inquiry-Driven Collaborative Learning (IDCL) model proposed by Zakariya (2025). Although these models differ in their instructional procedures, they all emphasis learners' active participation in the learning process, collaborative knowledge construction, critical thinking, and conceptual understanding. Among these models, the Inquiry-Driven Collaborative Learning (IDCL) model provides a structured framework that integrates direct instruction with guided inquiry and collaborative learning activities. The model begins with focused teacher guidance to introduce essential concepts, followed by collaborative inquiry in which students work together to investigate problems, construct mathematical understanding, justify their reasoning, and communicate their findings. This balanced instructional approach enables learners to develop deeper conceptual understanding while receiving adequate instructional support (Zakariya, 2025).

Furthermore, IDCL can be enriched with artificial intelligence tools such as ChatGPT during the collaborative inquiry phases. In this approach, students use ChatGPT to generate explanations, explore alternative solution methods, clarify difficult concepts, receive immediate feedback, and verify mathematical reasoning while working collaboratively. The integration of ChatGPT within the active inquiry stages enhances collaborative knowledge construction, promotes deeper conceptual understanding, sustains students' engagement, and supports independent learning. Previous studies have demonstrated that inquiry-based instructional models improve students' conceptual understanding, critical thinking, learning engagement, and attitudes towards mathematics (Jaworski et al., 2021; McInroy, 2025). Consequently, this study adopted the Inquiry-Driven Collaborative Learning (IDCL) model, with and without ChatGPT enrichment, as the instructional framework for teaching calculus. Recent advances in educational technology have further enhanced opportunities for inquiry-based instruction. Technology integration provides learners with dynamic tools that support exploration, visualization, collaboration, and personalized feedback. Digital technologies such as virtual laboratories, learning management systems, augmented reality, and artificial intelligence applications have become important resources for facilitating inquiry processes (Hinostroza et al., 2024; McKinney, 2021). Technology-supported inquiry environments have been found to improve student engagement, motivation, and learning outcomes by providing immediate feedback and adaptive learning experiences (Adhami & Taghizadeh, 2024; Kamarudin et al., 2024).

Among emerging technologies, ChatGPT has gained considerable attention as a powerful artificial intelligence tool capable of supporting teaching and learning. ChatGPT functions as a conversational learning assistant that can generate explanations, answer questions, provide feedback, and support problem-solving activities. Within inquiry-based classrooms, ChatGPT can assist students in generating questions, exploring multiple solution strategies, clarifying misconceptions, and reflecting on their learning processes (Kasneci et al., 2023). Research suggests that ChatGPT reduces anxiety, promotes learner autonomy, and enhances students' attitudes toward learning mathematics (Holstein et al., 2018; Zawacki-Richter et al., 2019). The integration of ChatGPT into Inquiry-Based Learning aligns with contemporary educational goals that emphasize student-centred learning, digital literacy, and technology-enhanced instruction. However, empirical evidence regarding the effectiveness of Inquiry-Based Learning enriched with ChatGPT on students' attitudes toward calculus remains limited, particularly among NCE students in Kaduna State, Nigeria. This study therefore investigates the effect of Inquiry-Based Learning enriched with ChatGPT on students' attitudes toward calculus among NCE awarding institutions in Kaduna State. Accordingly, the present study was designed to address these identified gaps by investigating the effect of integrating ChatGPT into an Inquiry-Driven Collaborative Learning (IDCL) environment on the attitudes of pre-service mathematics teachers towards calculus using a quasi-experimental research design. Specifically, the study sought to answer the following research questions:

1. What is the effect of Inquiry-Driven Collaborative Learning (IDCL) enriched with ChatGPT on students' attitudes towards calculus?
2. What is the effect of Inquiry-Driven Collaborative Learning (IDCL) without ChatGPT on students' attitudes towards calculus?

By addressing these research questions, the study contributes to three interrelated areas of scholarship. First, it advances mathematics education by providing empirical evidence on improving calculus learning and strengthening the preparation of pre-service mathematics teachers. Second, it contributes to the growing body of knowledge on Inquiry-Driven Collaborative Learning by examining how artificial intelligence, particularly ChatGPT, can serve as a scaffold to support collaborative inquiry and conceptual understanding. Third, it enriches the field of AI-enhanced learning by offering theoretically grounded and methodologically rigorous evidence regarding the pedagogical value of ChatGPT in mathematics instruction. The findings of this study are expected to be particularly valuable for teacher education programmes seeking to develop graduates who are not only mathematically competent but also capable of integrating emerging artificial intelligence technologies into teaching and learning in a responsible and pedagogically meaningful manner. Furthermore, by employing a quasi-experimental research design, the study provides stronger causal evidence than much of the existing literature, which has largely relied on descriptive or observational approaches. The subsequent sections of this paper present the theoretical framework, research methodology, findings, discussion, and implications of the study for mathematics teacher education and AI-enhanced learning.

# 2 Literature Review/Theoretical Framework

## 2.1 Concept of Students' Attitude toward Calculus

Attitude toward mathematics refers to a learner's disposition, beliefs, emotions, and behavioural tendencies regarding mathematics and its learning processes. According to Zakariya (2017), attitude encompasses perceptions of difficulty, confidence, anxiety, enjoyment, and perceived usefulness of mathematics. Attitudes influence students' engagement levels, persistence in solving mathematical problems, and willingness to participate in classroom activities. Positive attitudes contribute significantly to students' motivation, engagement, and academic achievement, while negative attitudes often result in avoidance behaviours and mathematics anxiety. According to (Yang et al., 2020). Positive attitudes toward mathematics are associated with increased achievement, motivation, and self-efficacy. Conversely, negative attitudes often manifest as mathematics anxiety, avoidance behaviours, and reduced academic performance. Among preservice teachers, attitudes toward mathematics are particularly important because they influence future classroom practices and students' perceptions of the subject. Students' attitudes toward calculus are particularly important because calculus concepts are abstract and cognitively demanding. Learners who perceive calculus as useful and manageable are more likely to persist in solving mathematical problems and engage actively in classroom activities. Conversely, negative perceptions often hinder learning and contribute to poor academic performance.

## 2.2 Inquiry-Based Learning and Students' Attitude

Inquiry-Based Learning is a student-centred instructional approach that encourages learners to construct knowledge through questioning, investigation, exploration, and reflection (Arega & Hunde, 2025). Rooted in constructivist learning theories, IBL positions students as active participants in the learning process rather than passive recipients of information. According to Jaworski et al. (2021), inquiry-based instruction promotes deeper conceptual understanding and encourages students to take ownership of their learning. Through inquiry activities, learners develop confidence in their mathematical abilities and become more willing to engage with challenging concepts. McInroy (2025) reported that inquiry-oriented learning environments enhance motivation, curiosity, and positive attitudes toward mathematics. Furthermore, IBL reduces mathematics anxiety by creating supportive learning environments where students are encouraged to explore multiple solution pathways without fear of failure. Such environments foster autonomy, collaboration, and self-confidence, thereby contributing to positive attitudes toward calculus (Sichangi, 2024).

## 2.3 Technology Integration in Inquiry-Based Classrooms

Technology integration has become an important component of modern inquiry-based instruction. Technology provides learners with opportunities for visualization, experimentation, collaboration, and personalized learning experiences. Digital tools support inquiry processes by enabling students to access information, conduct investigations, simulate mathematical phenomena, and receive immediate feedback (McKinney, 2021; Hinostroza et al., 2024). Studies have shown that technology-enhanced inquiry environments improve student engagement, content mastery, critical thinking, and motivation (Adhami & Taghizadeh, 2024). Technology also promotes differentiated instruction by providing scaffolded support and adaptive learning pathways that accommodate diverse learner needs (Kamarudin et al., 2024; Wen et al., 2023). Despite these benefits, successful technology integration requires adequate infrastructure, internet access, teacher preparedness, and alignment between technology use and pedagogical objectives (Gerard et al., 2011; Medeiros Cunha et al., 2020).

## 2.4 Artificial Intelligence and ChatGPT in Inquiry-Based Learning

Recent developments in artificial intelligence have expanded the technological tools available for supporting inquiry-based instruction. ChatGPT, a large language model powered by artificial intelligence, offers personalized learning support through conversational interactions. It can generate explanations, answer questions, provide feedback, and guide students through problem-solving activities (Kasneci et al., 2023). Within inquiry-based mathematics classrooms, ChatGPT functions as a cognitive partner that assists learners in generating hypotheses, exploring alternative solution methods, and reflecting on their understanding. Holstein et al. (2023) observed that AI-powered learning tools enhance learner engagement and promote self-regulated learning. Similarly, Zawacki-Richter et al. (2019) reported that conversational AI systems reduce anxiety and increase students' willingness to participate in STEM learning activities. When integrated into calculus instruction, ChatGPT can support conceptual understanding by helping students interpret mathematical notation, explore multiple problem-solving approaches, and receive formative feedback. Such support may contribute to improved confidence and more positive attitudes toward mathematics learning.

## 2.5 Theoretical Framework: Social Cognitive Theory

This study is anchored on the Social Cognitive Theory (SCT) developed by Bandura (1986). Social Cognitive Theory explains human learning as a dynamic process resulting from the reciprocal interaction of personal factors, behavioural patterns, and environmental influences, a concept Bandura described as triadic reciprocal determinism. According to the theory, individuals are not passive recipients of information; rather, they actively construct knowledge through observation, experience, social interaction, and self-reflection within their learning environments (Bandura, 1986). A central construct of Social Cognitive Theory is self-efficacy, defined as an individual's belief in his or her capability to organise and execute the actions required to achieve specific learning goals (Bandura, 1997). Students with high self-efficacy are more likely to approach challenging tasks with confidence, persist when faced with difficulties, employ effective learning strategies, and demonstrate greater academic achievement and positive attitudes towards learning. Conversely, students with low self-efficacy are more likely to experience anxiety, avoid challenging tasks, and develop negative attitudes toward academic subjects, particularly mathematics and calculus, which are often perceived as difficult (Bandura, 1997; Schunk & DiBenedetto, 2020).

Within the framework of Social Cognitive Theory, learning is enhanced when students engage in collaborative activities, receive constructive feedback, observe successful problem-solving strategies, and participate in environments that encourage active knowledge construction. These conditions are consistent with the principles of Inquiry-Driven Collaborative Learning (IDCL), which combines structured teacher guidance, collaborative inquiry, and active student participation to promote meaningful learning (Zakariya, 2025). Through collaborative problem-solving and guided inquiry, learners observe peers' reasoning processes, exchange ideas, receive timely support from instructors, and gradually develop confidence in solving mathematical problems. The integration of ChatGPT into the IDCL model further strengthens the environmental component of Social Cognitive Theory by providing learners with immediate explanations, personalised feedback, multiple solution strategies, and opportunities for self-regulated learning. ChatGPT enables students to ask questions freely, clarify misconceptions, receive instant formative feedback, and explore alternative approaches to solving calculus problems. These interactions enhance learners' confidence, support independent learning, and foster positive beliefs about their mathematical capabilities. In turn, improved self-efficacy contributes to more favourable attitudes towards calculus, greater persistence in solving complex problems, and increased engagement in learning activities (Bandura, 1977; Schunk & DiBenedetto, 2020; Zawacki-Richter et al., 2019).

The present study conceptualises the instructional approach as the environmental factor, students' attitudes towards calculus as the personal factor, and their engagement in learning activities and successful completion of calculus tasks as the behavioural outcomes, consistent with Bandura's triadic reciprocal determinism. Specifically, the use of Inquiry-Driven Collaborative Learning enriched with ChatGPT creates a supportive learning environment that encourages active participation, collaborative knowledge construction, and continuous feedback. These environmental experiences are expected to strengthen students' self-efficacy, improve their attitudes towards calculus, and ultimately enhance their learning outcomes. Therefore, Social Cognitive Theory provides a robust theoretical foundation for explaining how the integration of ChatGPT into Inquiry-Driven Collaborative Learning can influence pre-service mathematics teachers' attitudes toward learning calculus.

# 3 Materials and Methods

## 3.1 Research Design

This study adopted a quantitative pretest-posttest quasi-experimental non-equivalent control group design research design. A sample of 133 students participated in the study. Multistage sampling was adopted, at the first stage three public college of education were selected through simple random sampling. Thereafter, intact NCE II mathematics classes from the selected institutions were used for the experiment. Finally, balloting was used to assign the intact classes into the two experimental groups and one control group. The design was considered appropriate because intact classes were used as experimental units without the random assignment of individual participants to treatment groups, thereby preserving the natural classroom setting while allowing for the comparison of instructional interventions. The study comprised three instructional groups. Experimental Group I (EG I) was taught using the Inquiry-Driven Collaborative Learning (IDCL) model enriched with ChatGPT (IDCL+ChatGPT), in which students engaged in structured collaborative inquiry while using ChatGPT as an artificial intelligence learning support tool for generating explanations, exploring alternative solution strategies, receiving immediate feedback, and clarifying difficult calculus concepts. Experimental Group II (EG II) was taught using the Inquiry-Driven Collaborative Learning (IDCL) model only, following the same inquiry-driven collaborative instructional procedures but without access to ChatGPT. The Control Group (CG) was taught using the Conventional Teaching Method (CTM), characterised by teacher-centred instruction, explanation, demonstration, and individual practice. Prior to the commencement of the instructional intervention, all groups were administered a pretest to determine their baseline attitudes toward calculus. Following the completion of the treatment period, a posttest was administered using the same instrument to assess changes in students' attitudes attributable to the instructional approaches. The pretest scores also served as covariates during data analysis to control for initial group differences and to provide a more accurate estimate of the treatment effects.

## 3.2 Participants

The population comprised 1,122 NCE II mathematics students enrolled in public NCE-awarding institutions in Kaduna State, Nigeria. These students were studying calculus as part of their mathematics education programme. A sample of 133 NCE II Mathematics students participated in the study. The participants were selected using a multistage sampling procedure. First, three public NCE-awarding institutions were selected from the study population, after which one intact NCE II Mathematics class was selected from each institution. The three intact classes were then assigned to the treatment conditions**.** Experimental Group I (EG I)**,** which received Inquiry-Driven Collaborative Learning enriched with ChatGPT (IDCL+ChatGPT)**,** consisted of 53 students**.** Experimental Group II (EG II)**,** which received Inquiry-Driven Collaborative Learning (IDCL) only**,** comprised 45 students**.** The Control Group (CG)**,** which was taught using the Conventional Teaching Method (CTM)**,** consisted of 35 students**.**

## 3.3 Instrumentation

Data were collected using the Calculus Attitude Questionnaire (CAQ**)**. The instrument measured students' attitudes toward calculus across dimensions such as interest, confidence, anxiety, and perceived usefulness of calculus. The questionnaire was subjected to expert validation and reliability testing before administration. The Calculus Attitude Questionnaire was adapted from Zakariya (2017) to measure students' attitudes toward learning calculus. The CAQ Items was structured on a five-point Likert scale ranging from Strongly Agree (5) to Strongly Disagree (1) for positive statements, while negative statements was reverse-coded. Two dimensions of the original attitude scale developed by Zakariya (2017) Perception of Difficulty (PoF) and Feelings of Anxiety toward Mathematics (FoA) were retained. These dimensions were selected because they represent the core affective variables most directly linked to students' learning behaviour and performance in calculus, especially within the context of Colleges of Education in Nigeria. The final 15-item CAQ reliability was 0.81 therefore provides a valid, reliable, and domain-specific measure of students' attitudes toward calculus for the purposes of this study. In order to establish the construct validity of CAQ, the confirmatory factor analysis (CFA) of the 15-item two-factor CAQ was conducted. This analytical process offered the opportunity to judge the consistency of the two-factor hypothesised model of CAQ and the data generated during the pilot study (Brown, 2015).

## 3.4 Treatment Procedure

The experimental groups were instructed using the Inquiry-Driven Collaborative Learning (IDCL) model developed by Zakariya (2025). The IDCL model integrates focused direct instruction with structured inquiry and collaborative learning activities to foster deep conceptual understanding, active engagement, and meaningful knowledge construction. The intervention was implemented over a 12-week semester, with one two-hour instructional session conducted each week. The calculus content covered during the intervention included integration as the reverse process of differentiation, integration as the area under a curve, techniques of integration (substitution, partial fractions, integration by parts, and reduction formula), integration of transcendental functions, numerical integration, and applications of integration**.** Each instructional topic was organised into two complementary phases in accordance with the IDCL model. The two phases were either completed within a single two-hour session (one hour per phase) or delivered over two consecutive weeks, with the first week devoted to Phase One and the second week to Phase Two. During Phase One, the researcher provided focused direct instruction through concise lectures, guided demonstrations, digital learning resources, and pre-class instructional materials. This phase was designed to introduce fundamental concepts, mathematical notation, computational procedures, and practical applications of the topic under study, thereby establishing the foundational knowledge required for inquiry activities.

During Phase Two, students participated in inquiry-driven collaborative learning activities. They were randomly assigned to small groups, and each group received specific subtopics or sets of calculus problems for investigation. Group members collaboratively explored the assigned tasks, solved ill-structured calculus problems, developed multiple solution strategies, and formulated their own inquiry questions to deepen conceptual understanding and stimulate mathematical reasoning. Throughout the collaborative inquiry process, the researcher assumed the role of a facilitator by providing instructional scaffolding, posing probing questions, encouraging critical thinking, and gradually reducing support as students became more confident and independent in solving mathematical problems. At the conclusion of each session, the groups presented their findings, submitted their solutions together with the inquiry questions they had generated, and participated in formative assessment activities. Constructive qualitative feedback was provided on the quality of their presentations, mathematical reasoning, problem-solving approaches, communication skills, and problem-posing abilities. The implementation of the IDCL model promoted active participation, collaborative knowledge construction, critical thinking, conceptual understanding, and sustained engagement with calculus concepts.

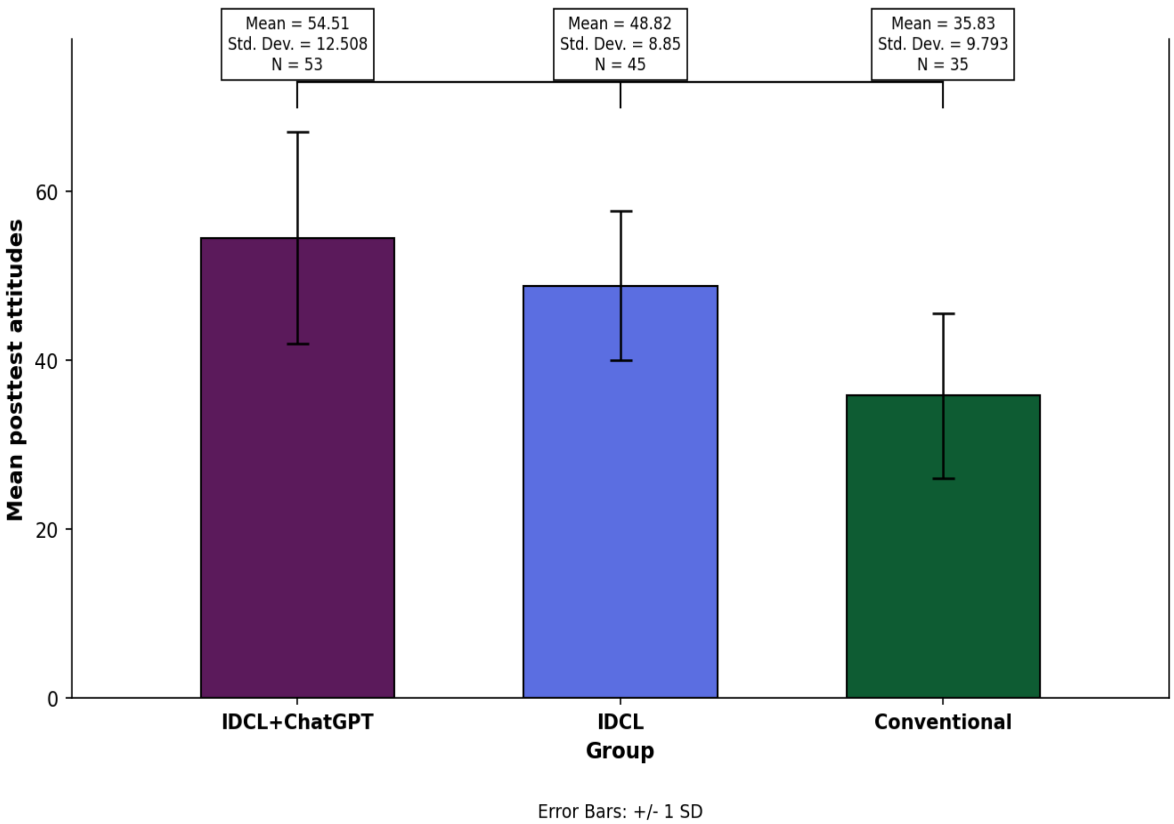
Students in the IDCL enriched with ChatGPT (IDCL+ChatGPT) group participated in the same instructional activities as those in the IDCL-only group but were additionally permitted to interact with ChatGPT during the collaborative inquiry phase. Prior to the commencement of the intervention, these students attended a one-day training workshop on the fundamentals of generative artificial intelligence, effective prompt engineering, and the ethical use of ChatGPT for educational purposes. During the intervention, ChatGPT served as a learning assistant by providing explanations of calculus concepts, generating alternative solution strategies, delivering immediate formative feedback, assisting students in verifying their mathematical reasoning, and supporting independent and collaborative learning throughout the inquiry process.

## 4 Results

To address the first research question, the post-test composite attitude scores of the two experimental groups and the control group were analysed using descriptive statistics. Figure 4.1 presents the post-test mean attitude scores of NCE students who were taught calculus using Inquiry-Driven Collaborative Learning enriched with ChatGPT (IDCL+ChatGPT)**,** Inquiry-Driven Collaborative Learning (IDCL) only**,** and the Conventional Teaching Method (CTM).

Figure **4.1**

*Summary statistics for post-test attitudes scores of students in experimental and control groups*




The results presented in Figure 4.1 indicate that students exposed to the Inquiry-Driven Collaborative Learning enriched with ChatGPT (IDCL+ChatGPT) intervention obtained the highest mean attitude score **(**M = 54.51, SD = 12.51, N = 53**),** followed by students taught using Inquiry-Driven Collaborative Learning (IDCL) **(**M = 48.82, SD = 8.85, N = 45**),** while students taught using the Conventional Teaching Method (CTM) recorded the lowest mean attitude score **(**M = 35.83, SD = 9.79, N = 35). The error bars further reveal visible differences in the distribution of scores across the three instructional groups, suggesting that the instructional approach may have influenced students' attitudes towards calculus. With respect to Research Question One**,** which sought to determine the mean difference in the attitudes of students taught calculus using Inquiry-Driven Collaborative Learning (IDCL) and those taught using the Conventional Teaching Method (CTM)**,** the findings indicate that students in the IDCL group demonstrated a substantially higher mean attitude score than those in the conventional group. Specifically, the observed mean difference between the two groups was 12.99 points (48.82 − 35.83) in favour of the IDCL group. This finding suggests that exposing students to the Inquiry-Driven Collaborative Learning model enhanced their attitudes towards learning calculus compared with the traditional teacher-centred instructional approach.

**Testing Hypothesis One**

$H_{01}$: There is no significant difference in the mean attitude scores of NCE students taught calculus using Inquiry-Driven Collaborative Learning (IDCL) and those taught using the Conventional Teaching Method (CTM)**.**

Before testing Hypothesis One, the post-test attitude scores were examined for normality to determine whether the assumptions underlying the use of parametric statistical tests were satisfied. The results of the normality assessment are presented in Table 4.1**.**

Table **4.1**

*Tests of Normality for post-test attitudes*

| **Group** | **Kolmogorov-Smirnov[a]** | | | **Shapiro-Wilk** | | |
|---|---|---|---|---|---|---|
| | **Statistic** | **Df** | **p-value** | **Statistic** | **Df** | **P -value** |

| | | | | | | |
|---|---|---|---|---|---|---|
| IDCL+AI | 0.121 | 53 | 0.050 | 0.877 | 53 | 0.000 |
| IDCL | 0.089 | 45 | 0.200* | 0.961 | 45 | 0.132 |
| Conventional | 0.129 | 35 | 0.148 | 0.896 | 35 | 0.003 |

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

The results presented in Table 4.1 indicate that the post-test attitude scores did not substantially deviate from normality, as the Kolmogorov–Smirnov test was not statistically significant across the three instructional groups (p-values ranging from 0.050 to 0.200**).** The Shapiro–Wilk test for the Inquiry-Driven Collaborative Learning (IDCL) group was also not statistically significant (p = .132), corroborating the findings of the Kolmogorov–Smirnov test. Although the Shapiro–Wilk test was statistically significant for the Inquiry-Driven Collaborative Learning enriched with ChatGPT (IDCL+ChatGPT) group and the Conventional Teaching Method (CTsM) group, indicating slight departures from normality, these deviations were not considered substantial enough to violate the normality assumption. Given the robustness of Analysis of Covariance (ANCOVA) to minor violations of normality, particularly when group sizes are reasonably balanced, the assumption of normality was considered to have been adequately satisfied. Consequently, Analysis of Covariance (ANCOVA) was employed to **test** Hypotheses One, Two, and Three**,** using the pre-test attitude scores as the covariate to control for initial differences among the groups. The results of the ANCOVA are presented in Table 4.2**.**

Table **4.2**

*Summary of ANCOVA statistics for attitudes scores*

| Source | Type III Sum of Squares | Df | Mean Square | F-value | p-value | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 7840.961[a] | 3 | 2613.654 | 23.335 | <.001 | .352 |
| Intercept | 7198.759 | 1 | 7198.759 | 64.272 | <.001 | .333 |
| Pretest Attitudes | 394.311 | 1 | 394.311 | 3.521 | .063 | .027 |
| Group | 6189.354 | 2 | 3094.677 | 27.630 | <.001 | .300 |
| Error | 14448.483 | 129 | 112.004 | | | |
| Total | 324512.000 | 133 | | | | |
| Corrected Total | 22289.444 | 132 | | | | |

a. R Squared = .352 (Adjusted R Squared = .337)

Table 4.2 presents the results of the ANCOVA conducted to determine whether significant differences existed in the post-test attitudes of NCE students taught calculus using IDCL enriched with ChatGPT, inquiry Driven Collaborative Learning (IDCL), and the conventional teaching method after controlling for students' pretest attitude scores. The ANCOVA results revealed that the overall corrected model was statistically significant, ($F(3,129) = 23.335, p < .05$), with a partial eta squared value of $.352$. This indicates that the model explained approximately 35.2% of the variance in students' post-test attitudes towards calculus. The adjusted (R-squared) value of 0.337 further suggests that the instructional approaches and covariate jointly contributed substantially to explaining variations in students' attitudes. Further, Table 4.2 shows that the covariate, pretest attitudes, was not statistically significant, ($F(1,129) = 3.521, p = 0\ .063$), with a partial eta squared of $0.027$. This implies that students' initial attitudes towards calculus did not significantly influence their post-test attitudes after accounting for the effects of the instructional groups. In contrast, the main effect of group was statistically significant, ($F(2,129) = 27.630, p < 0.05$), with a partial eta squared value of .300. This finding indicates that significant differences existed among the adjusted mean attitude scores of students across the three instructional groups. The partial eta squared value further suggests a large effect size, implying that the instructional strategies had a substantial influence on students' attitudes towards calculus. To identify the specific groups responsible for the observed significant difference, Bonferroni post hoc pairwise comparisons were conducted. The results of these pairwise comparisons of means are presented in Table 4.3.

Table **4.3**

*Bonferroni pairwise comparisons of means of attitudes scores*

| (I) Group | (J) Group | Mean Difference (I-J) | Std. Error | Sig.[b] | 95% Confidence Interval for Difference[b] |
|---|---|---|---|---|---|

| | | | | | Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|
| IDCL+ChatGPT | IDCL | 4.981 | 2.178 | .071 | -.302 | 10.264 |
| | Conventional | 17.524* | 2.386 | <.001 | 11.736 | 23.312 |
| IDCL | IDCL+ChatGPT | -4.981 | 2.178 | .071 | -10.264 | .302 |
| | Conventional | 12.543* | 2.397 | <.001 | 6.728 | 18.357 |
| Conventional | IDCL+ChatGPT | -17.524* | 2.386 | <.001 | -23.312 | -11.736 |
| | IDCL | -12.543* | 2.397 | <.001 | -18.357 | -6.728 |

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

The presented results in Table 3 revealed that the difference between students taught using IDCL and those taught using the conventional method was statistically significant, with an estimated marginal mean difference of 12.543 and ($p < .001$). Since the probability value is less than the .05 level of significance, the null hypothesis stating that there is no significant difference in the attitudes of students taught calculus using IDCL and those taught using the conventional method was rejected. These results indicate that inquiry-based learning significantly improved students' attitudes towards calculus when compared with the conventional teaching method.

**Addressing Research Question Two**

What is the mean difference in the attitude of NCE students taught calculus using IDCL and those taught using IDCL enriched with ChatGPT?

The presented results in Figure 1 show that students taught using IDCL enriched with ChatGPT exhibited more favourable attitudes towards calculus than those taught using IDCL-only. The mean difference between the IDCL+ChatGPT group and the IDCL group was 5.69 points (54.51 - 48.82), indicating that the integration of ChatGPT into inquiry-based learning may have provided additional learning support capable of improving students' attitudes towards calculus.

**Testing Hypothesis Two**

$H_{O2}$: There is no significant difference in the mean attitudes of NCE students taught calculus using IDCL and those taught using IDCL enriched with ChatGPT.

The presented results in Table 4.3 showed that the difference between students taught using IBL enriched with ChatGPT and those taught using IDCL alone was not statistically significant, with an estimated marginal mean difference of 4.981 and ($p = .071$). Since the probability value exceeded the .05 level of significance, the null hypothesis stating that there is no significant difference in the attitudes of students taught calculus using IDCL and those taught using IDCL enriched with ChatGPT was retained. This suggests that although the IDCL+ChatGPT group recorded a higher adjusted mean attitude score, the observed difference was not sufficiently large to reach statistical significance.

**Addressing Research Question Three**

What is the mean difference in the attitude of NCE students taught calculus using IDCL enriched with ChatGPT and those taught using the conventional method?

The presented results in Figure 1 show that students taught using IDCL enriched with ChatGPT exhibited more favourable attitudes towards calculus than those taught using the conventional method. The mean difference between the IDCL+ChatGPT group and the conventional group was 18.68 points ($54.51 - 35.83$), representing the largest observed difference among the comparisons.

**Testing Hypothesis Three**

$H_{O3}$: There is no significant mean difference in the attitude of NCE students taught calculus using IDCL enriched with ChatGPT and those taught using the conventional method.

The presented results in Table 4.3 revealed that the comparison between the IDCL+ChatGPT group and the conventional group revealed a statistically significant estimated marginal mean difference of 17.524 in favour of the IDCL+ChatGPT group, with ($p < .05$). Since the probability value is less than the .05 level of significance, the null hypothesis stating that there is no significant difference in the attitudes of students taught calculus using IDCL enriched with ChatGPT and those taught using the conventional method was rejected. These results indicate that inquiry-based learning especially when enriched with ChatGPT significantly improved students' attitudes towards calculus when compared with the conventional teaching method.

## 5 Discussion of Findings

The findings of this study revealed that students taught calculus using Inquiry-Driven Collaborative Learning (IDCL) developed significantly more positive attitudes toward calculus than students taught using the Conventional Teaching Method (CTM)**.** This finding suggests that the IDCL instructional environment, which integrates focused direct instruction with structured inquiry and collaborative learning activities, promotes greater learner participation, autonomy, curiosity, and confidence in learning calculus. Students who actively explored concepts, formulated inquiry questions, collaborated with peers, and participated in guided mathematical investigations developed more favourable perceptions of calculus than those who learned through teacher-centred instruction. This finding is consistent with the work of Robinson and Aldridge (2022), who reported that inquiry-based classroom environments significantly improved students' attitudes toward mathematics by reducing mathematics anxiety and increasing learner autonomy. Similarly, the findings agree with Baber and Qureshi (2021), who observed that inquiry-oriented instructional approaches enhanced students' motivation, critical thinking, problem-solving skills, and overall learning experiences. The positive attitudes observed among participants in the present study also support Wheatley's (2018) assertion that inquiry-centred instructional activities increase students' enjoyment, participation, and enthusiasm for learning mathematics. The present study extends these findings by demonstrating that the structured and collaborative features of the Inquiry-Driven Collaborative Learning (IDCL) model are equally effective in promoting positive attitudes toward calculus among pre-service mathematics teachers.

The study further revealed that students exposed to Inquiry-Driven Collaborative Learning enriched with ChatGPT (IDCL+ChatGPT) demonstrated significantly more positive attitudes toward calculus than those taught using the Conventional Teaching Method (CTM)**.** The integration of ChatGPT into the collaborative inquiry process provided immediate feedback, personalised explanations, alternative solution strategies, and continuous academic support, all of which may have strengthened students' confidence and reduced anxiety while learning calculus. Through interactions with ChatGPT, students were able to clarify misconceptions, verify mathematical reasoning, and explore multiple approaches to solving calculus problems, thereby enriching their learning experiences. However, the study found that although students taught using IDCL enriched with ChatGPT achieved higher attitude scores than those taught using IDCL alone**,** the difference was not statistically significant. This finding suggests that the structured inquiry and collaborative learning processes embedded in the IDCL model were the principal factors responsible for improving students' attitudes toward calculus. Although ChatGPT served as an effective instructional scaffold by providing additional explanations and immediate feedback, its contribution to attitude development was not sufficiently large to produce a statistically significant advantage beyond that already achieved through the IDCL instructional approach.

These findings are consistent with Social Cognitive Theory (Bandura, 1986, 1997), which posits that learning results from the reciprocal interaction of environmental, personal, and behavioural factors. Within the context of this study, the IDCL learning environment constituted the environmental factor by providing opportunities for collaborative inquiry, guided instruction, modelling, and continuous feedback. These experiences enhanced students' self-efficacy and confidence (personal factors), which, in turn, encouraged greater participation and persistence in learning calculus (behavioural outcomes). The integration of ChatGPT further strengthened this learning environment by offering timely instructional support and opportunities for self-regulated learning, thereby reinforcing students' positive attitudes toward calculus. Overall, the findings indicate that Inquiry-Driven Collaborative Learning (IDCL) represents an effective pedagogical approach for improving students' attitudes toward calculus. Although integrating ChatGPT enriched the learning experience by providing personalised assistance and immediate formative feedback, its incremental contribution to attitude development was less pronounced than its contribution to learning engagement and academic performance. Consequently, mathematics educators should consider adopting the Inquiry-Driven Collaborative Learning (IDCL) model and integrating artificial intelligence tools such as ChatGPT to create more supportive, collaborative, and engaging learning environments for pre-service mathematics teachers in NCE.

## 6 Conclusion

This study investigated the effect of Inquiry-Driven Collaborative Learning enriched with ChatGPT (IDCL+ChatGPT) on students' attitudes toward calculus among NCE students in Kaduna State, Nigeria. The findings revealed that instructional strategy significantly influenced students' attitudes toward calculus. Specifically, students taught using Inquiry-Driven Collaborative Learning (IDCL) **and** Inquiry-Driven Collaborative Learning enriched with ChatGPT (IDCL+ChatGPT) developed more positive attitudes toward calculus than those taught using the Conventional Teaching Method (CTM)**.** The study established that the Inquiry-Driven Collaborative Learning (IDCL) model provides a learner-centred instructional environment that combines focused teacher guidance with structured inquiry and collaborative learning. This instructional approach encouraged active participation, collaboration, exploration, critical thinking, and meaningful knowledge construction, thereby enhancing students' confidence, interest, motivation, and willingness to engage with calculus concepts. Consequently, students exposed to the IDCL instructional approach demonstrated more favourable attitudes toward calculus than those who learned through conventional teacher-centred instruction.

The findings further indicated that although students taught using IDCL enriched with ChatGPT obtained higher attitude scores than those taught using IDCL alone, the difference was not statistically significant. This suggests that the structured inquiry and collaborative learning processes embedded within the IDCL model were primarily responsible for improving students' attitudes toward calculus. Nevertheless, ChatGPT served as an effective learning assistant by providing personalised explanations, immediate formative feedback, guided inquiry support, and opportunities for self-directed learning, thereby enriching students' overall learning experiences. The study therefore concludes that Inquiry-Driven Collaborative Learning (IDCL) is an effective instructional model for fostering positive attitudes toward calculus among NCE students. Furthermore, enriching the IDCL model with ChatGPT creates a more supportive and interactive learning environment that promotes self-regulated learning, confidence, and meaningful engagement with mathematical concepts. Mathematics educators and teacher education institutions should therefore adopt the Inquiry-Driven Collaborative Learning (IDCL) model and strategically integrate emerging artificial intelligence tools such as ChatGPT into mathematics instruction to enhance students' learning experiences and cultivate more positive attitudes toward calculus.

## 7 Limitation of the Study

1. The study employed a quasi-experimental design using intact classes rather than random assignment of individual students, which may have introduced pre-existing group differences despite the use of ANCOVA to control for baseline attitudes.
2. The study was conducted in three public NCE-awarding institutions in Kaduna State with a sample of 133 NCE II Mathematics students; therefore, the findings may not be fully generalizable to private colleges, other states, or different educational levels.
3. The intervention lasted 12 weeks, which was sufficient to examine short-term changes in students’ attitudes but did not assess the long-term sustainability of these effects.
4. The study focused only on attitude toward calculus; other important variables such as knowledge retention, self-efficacy, digital literacy, and long-term academic achievement were not investigated. These limitations provide opportunities for future studies to employ randomized designs, larger and more diverse samples, longer intervention periods, and additional cognitive and affective outcomes.

## 8 Suggestions for Future Research

1. Future studies should investigate whether the positive effects of IDCL and IDCL+ChatGPT on students’ attitudes toward calculus are sustained over longer periods.
2. Future researchers should replicate the study using larger samples involving more NCE-awarding institutions, including both public and private institutions and different geographical regions, to improve the generalisability of the findings.
3. Future studies should examine outcomes beyond attitude, including academic performance, learning engagement, self-efficacy, critical thinking, problem-solving ability, and knowledge retention, to provide a more comprehensive understanding of IDCL+ChatGPT.
4. Future research should investigate students’ experiences, digital competence, and patterns of ChatGPT use through qualitative or mixed-methods approaches to better explain how AI-supported inquiry learning influences students’ learning and attitudes.

## 9 Recommendations

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

1. Mathematics lecturers in Colleges of Education should adopt the Inquiry-Driven Collaborative Learning (IDCL) model as a regular instructional approach for teaching calculus and other mathematics courses because it combines focused direct instruction with structured inquiry and collaborative learning, thereby promoting positive attitudes, active participation, critical thinking, and deeper conceptual understanding.
2. Teacher education institutions should encourage the integration of ChatGPT and other artificial intelligence tools into the Inquiry-Driven Collaborative Learning (IDCL) model to provide students with immediate academic support, personalised feedback, multiple problem-solving strategies, and opportunities for self-directed and collaborative learning.
3. Educational administrators should organise professional development programmes, workshops, and seminars to equip mathematics lecturers with the knowledge and skills required for the effective implementation of the Inquiry-Driven Collaborative Learning (IDCL) model and the pedagogically sound integration of artificial intelligence tools such as ChatGPT into mathematics instruction.
4. Curriculum developers and educational policymakers should incorporate the Inquiry-Driven Collaborative Learning (IDCL) model and AI-enhanced instructional approaches into mathematics education curricula to ensure that teaching practices reflect contemporary pedagogical innovations and prepare future teachers to integrate emerging technologies effectively.
5. Colleges of Education should improve access to digital infrastructure, reliable internet connectivity, computer laboratories, and other technological resources required for the successful implementation of IDCL enriched with ChatGPT and other AI-supported instructional approaches.
6. Pre-service mathematics teachers should be encouraged to use ChatGPT responsibly and ethically as a supplementary learning assistant during Inquiry-Driven Collaborative Learning (IDCL) activities to explore mathematical concepts, verify solutions, receive formative feedback, and strengthen independent learning and problem-solving skills.
7. Future researchers should investigate the long-term effects of Inquiry-Driven Collaborative Learning enriched with ChatGPT (IDCL+ChatGPT) on students' knowledge retention, critical thinking, self-efficacy, learning engagement, academic performance, and other cognitive and affective outcomes across different mathematical topics and educational contexts.

## 10 Declarations

**Ethics, Transparency & Completeness**: Ethical approval was obtained from the relevant institutional authorities before the commencement of the study. Permission was also obtained from the participating NCE-awarding institutions. The participants were informed about the purpose and procedures of the study, and their participation was voluntary. Participants were assured that the information provided would be treated confidentially and used strictly for research purposes. Informed consent was obtained from the participants before data collection.

**Conflict of Interest**: The authors declare that there is no conflict of interest associated with this study.

**Author Contribution**: All authors contributed to the conception and design of the study. The first author conducted data collection, data analysis, and preparation of the manuscript. The co-authors contributed to the supervision, interpretation of findings, critical review, and revision of the manuscript. All authors read and approved the final version of the manuscript.

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