Asian Journal of Applied Education (AJAE)
Vol. 4, No. 2, 2025: 217-232

Effectiveness of Interactive Teaching Strategies in Enhancing Achievement in Calculus: A Quasi-Experimental Research Design

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A R T I C L E I N F O

Keywords: Interactive Teaching Strategies, Traditional Lecture-Based Instructional Methods, Achievement in Calculus, Quasi-Experimental Research Design

Received : 25, March
Revised : 8, April
Accepted : 22, April

A B S T R A C T

This study investigates the effectiveness of interactive teaching strategies in improving calculus achievement among second-year pre-service teachers, employing a quasi-experimental design. Forty students were purposively sampled and exposed to both traditional direct instruction and interactive pedagogies. Quantitative data were analyzed using descriptive statistics, paired and independent t-tests, and Cohen's d to assess instructional impact. Findings indicate that while initial performance in calculus was low, both instructional approaches significantly enhanced student achievement. Direct instruction facilitated systematic skill acquisition, whereas interactive strategies promoted higher engagement and positive learning attitudes. Notably, the interactive approach demonstrated a stronger effect size, suggesting deeper conceptual understanding. The study concludes that a pedagogical blend of direct and interactive methods may offer optimal benefits by integrating structure with active student participation. These findings underscore the importance of responsive, evidence-based instructional design in mathematics education and highlight the transformative potential of interactive strategies in fostering calculus competence.

DOI prefik: https://doi.org/10.55927/ajae.v4i2.14201
ISSN-E: 2963-5241
https://journal.formosapublisher.org/index.php/ajae

INTRODUCTION

Mathematics plays a crucial role in understanding and solving real-world problems. Among its branches, calculus is a cornerstone in advanced education, particularly in engineering, economics, and the sciences. Despite its significance, calculus is often perceived as one of the most challenging subjects for students, leading to high failure rates and a lack of confidence in their mathematical abilities (Domondon et al., 2023; Hagman et al., 2015). This calls for reevaluating the pedagogical strategies employed in teaching this vital subject.

The traditional method of teaching calculus, characterized by lecture and teacher-centered instruction, has been the predominant approach for decades. Hill and MacMillan (2004) describe Direct Instruction (DI) as a teaching approach focusing on meticulously designed lessons structured around small, incremental learning steps and explicitly defined teaching tasks. This methodology can lead to significant and efficient student achievement when integrated into a robust and effective set of instructional strategies. According to Stockard et al. (2018), mastery learning is a fundamental component of DI. It emphasizes two critical aspects: first, ensuring that students have thoroughly grasped essential concepts before progressing to new material. Second, accurate placement within a curriculum is crucial to confirm that students possess the prerequisite knowledge to acquire new skills or concepts while avoiding unnecessary repetition of content they have already mastered. However, there are some criticisms about the efficiency of this method. They argue that DI is not the best teaching method and believe alternative methods are more effective. This perspective is most commonly held by educators who advocate for constructivist or discovery-based learning approaches (McMullen & Madelaine, 2014). This approach may hinder students from developing a deep conceptual understanding, leading to a reliance on procedural knowledge rather than problem-solving skills.

In contrast, interactive teaching strategies emphasize student-centered learning through activities encouraging collaboration, exploration, and active engagement (Arjomandi, 2018). Active learning encompasses a range of teaching approaches that prioritize student engagement and active participation in the learning process. Methods that support active learning involve instructional strategies where students actively engage in tasks while reflecting on their actions and outcomes (Roehl, Reddy, & Shannon, 2013). Techniques such as think-pair-share, inverted (or "flipped") classes, inquiry-based learning, peer instruction, group discussions, real-world problem-solving, and the use of technology in simulations have gained attention for their potential to enhance comprehension and retention in mathematics (Braun et al., 2017). Based on the study of Freeman et al. (2014) found that active learning enhances student performance in science, engineering, and mathematics. The study revealed that average exam scores in active learning environments improved by approximately 6%. Additionally, students in traditional lecture-based classes were 1.5 times more likely to fail than those in active learning settings. Through interactive methods, students develop professional competencies, enhance analytical thinking, harness cognitive abilities, cultivate an interest in acquiring new knowledge, and unlock their creative potential (Kutbiddinova et al., 2016). These methods make learning dynamic, fostering a deeper understanding of calculus concepts and their practical applications.

A review of existing literature reveals a growing body of evidence supporting the efficacy of interactive teaching methods. Research indicates that these approaches enhance academic performance and cultivate essential skills such as student communication and collaboration. However, despite these promising findings, there remains a notable gap in understanding how specific interactive strategies affect achievement in calculus across diverse educational contexts. Most studies have focused on general mathematics or other subjects, leaving a need for targeted research within calculus instruction.

In the evolving landscape of education, the quest for effective teaching methodologies is paramount, particularly in challenging subjects such as calculus. Traditional lecture-based approaches may fall short of engaging students and fostering deep understanding (Marette, 2024). In many classrooms, the teacher remains the central figure, imparting information in a one-way communication model that leaves little room for active student engagement or exploration (Bethel, 2024). Conversely, interactive teaching strategies have emerged as a promising alternative, emphasizing student participation and active learning. This study investigates the effectiveness of interactive teaching strategies in enhancing student achievement in calculus through a quasi-experimental research design.

The significance of this study lies in its potential to inform teaching practices and curriculum design in mathematics education. Educators can better support students' learning processes by identifying effective interactive strategies and enhancing their academic success in calculus. Hence, this study seeks to fill the existing gaps in the literature regarding interactive teaching methods in calculus education. A quasi-experimental design aims to provide empirical evidence on the effectiveness of these strategies, ultimately contributing to improved educational outcomes for students navigating the complexities of calculus.

LITERATURE REVIEW

In line with its overarching aim of evaluating the effectiveness of interactive teaching strategies in enhancing university students' achievement in calculus, this research study is directed toward several specific objectives. Firstly, it seeks to describe the students' performance in calculus based on the results of both the pre-test and post-test, thereby establishing a baseline and assessing progress over the course of the instructional intervention. Secondly, it aims to determine whether a significant difference exists between the pre-test scores of students in the controlled and intervention groups, providing an initial comparison of the two cohorts' mathematical competencies prior to exposure to different teaching strategies. Thirdly, the study endeavors to examine the significance of the difference between the pre-test and post-test scores of the controlled group, assessing any learning gains under traditional instructional methods. Similarly, it intends to analyze whether a statistically significant difference exists between the pre-test and post-test scores of the intervention group, thus measuring the impact of interactive teaching strategies on students' calculus achievement. Furthermore, the research aims to compare the post-test performance of the controlled and intervention groups, to determine whether the use of interactive strategies yields superior outcomes compared to conventional approaches. Lastly, the study aims to explore and describe the attitudes of students in the intervention group toward the use of interactive teaching strategies, offering insights into the learners' perceptions and receptiveness to the pedagogical approach. Through these objectives, the study aspires to generate robust empirical evidence to inform the pedagogical practices in mathematics education, particularly in the teaching and learning of calculus at the tertiary level.

Conceptual Framework

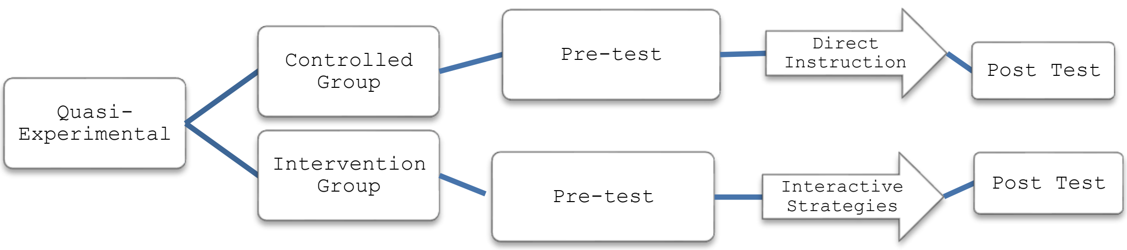

Figure 1. Research Paradigm

The conceptual framework illustrates a quasi-experimental research design that compares the effectiveness of two instructional methods. Participants are divided into two groups: a controlled and an intervention group. Both groups undergo a pre-test to assess their baseline knowledge or performance before the instructional phase. The controlled group receives direct instruction, representing the traditional teaching approach, while the intervention group engages in interactive strategies, offering a more dynamic and participatory learning experience. Following these instructional interventions, both groups take a post-test to evaluate the impact of the different methods. This framework highlights the structured process of assessing how interactive strategies influence learning outcomes compared to direct instruction, providing valuable insights into the effectiveness of diverse teaching approaches.

RESEARCH METHOD

Research Design

This study applied the quantitative method of research, particularly the quasi-experimental research design. Thomas (2024) states that a quasi-experimental design aims to establish a cause-and-effect relationship between an independent and dependent variable. A quasi-experimental design is useful when true experiments cannot be used for ethical or practical reasons. These methods have been integral in highlighting the strength and magnitude of the causal effects of key educational policies and interventions on well-defined student outcomes and, in some cases, have demonstrated the unintended consequences of specific education policies and interventions (Gopalan et al., 2020). This study seeks to assess the effectiveness of interactive teaching strategies in improving calculus achievement at the university level and compare its efficiency to direct instruction.

Respondents of the Study

The study employed purposive sampling, selecting forty (40) students from the second-year cohort of pre-service teachers at the College of Education, Nueva Ecija University of Science and Technology. The participants were chosen based on the following criteria: (1) currently enrolled as second-year Bachelor of Secondary Education (BSED) Mathematics majors, (2) classified as regular students, and (3) scheduled to study topics including basic rules of differentiation, higher-order derivatives, and implicit differentiation.

The participants were divided into two groups: the Intervention group and the Control group. Following the pre-test administration, a match-pairing technique was applied to ensure equivalency between the two groups based on their pre-test scores. Participants with identical scores were paired and then assigned to either the Control or Intervention group, with each group comprising 20 participants, resulting in 40 students.

Research Instrument

To attain the objectives of the present study, the researcher used three vital instruments: Learning Plans, Achievement Tests, and Attitudinal Questionnaire. The Learning Plans serve as structured guides outlining the instructional content and activities for both the controlled and intervention groups, ensuring consistency in delivery while accommodating the interactive strategies applied to the intervention group. The Achievement Test is designed to measure the participants' understanding and mastery of calculus concepts before and after the intervention, providing quantifiable data to assess the impact of the teaching strategies. Meanwhile, the Attitudinal Questionnaire gathers qualitative insights into the students' perceptions, engagement, and overall experience with the instructional methods used. These instruments enable a comprehensive evaluation of the academic outcomes and the attitudinal shifts resulting from the interactive teaching strategies.

Validation of the Research Instrument

The validation process ensured the accuracy and reliability of the study's instruments. Learning Plans were reviewed by calculus and education experts to ensure content alignment, clarity, and appropriateness, with feedback incorporated to refine instructional flow. The Achievement Test underwent content validation and alignment with the key competencies in calculus.

Initially, the test items were developed based on the learning objectives and essential topics covered in the course. The draft test was then reviewed by experienced calculus instructors and assessment specialists, who examined the items for relevance, clarity, and difficulty level. The Attitudinal Questionnaire was developed from existing frameworks and validated by education specialists through expert review and pilot testing. Internal consistency was measured using Cronbach's alpha (a = .921). This thorough process ensured all instruments effectively measured the study's objectives.

Data Gathering Procedure

The researcher began by securing ethical clearance and permission from school authorities to conduct the study. A pre-test was administered to establish baseline data and assign participants to either the control or intervention group based on their initial calculus performance. Research instruments were validated by subject matter experts and pilot-tested to ensure reliability and alignment with instructional objectives.

The experimental phase spanned six weeks, covering topics such as the Basic Rules of Differentiation, Higher Order Derivatives, and Implicit Differentiation. The control group received traditional lecture-based instruction, while the intervention group was taught using interactive strategies, including think-pair-share, guided inquiry, peer teaching, and digital tools for visualizing calculus concepts. These methods aimed to foster active engagement and deeper conceptual understanding.

Following the intervention, a post-test was administered to both groups to evaluate learning gains. The results were analyzed to assess the impact of the interactive strategies on student achievement in calculus.

Statistical Treatment of Data

The researcher used various statistical analyses to answer the research questions. First, frequency count and percentage were used to describe the control and intervention groups' pre-test and post-test scores. Second, a paired t-test was used to determine if there was a significant difference in the pre-test and post-test scores after implementing different teaching strategies. Third, an independent t-test was used to analyze the significant math achievement difference between controlled and intervention groups. Lastly, mean scores were used to describe the respondents' attitudes toward implementing interactive teaching strategies.

RESULT AND DISCUSSION

This study aims to determine the Comparative Analysis of Direct Instruction and Interactive Strategies in Teaching Differential Calculus. Specifically, it answered the following questions:

Achievements in the Calculus of Students Before and After the Instruction
Controlled Group

Table 1. Achievement in Calculus of Controlled Group

Scores	Pre-Test	%	Post-Test	%	Verbal Description
25-30	0	0.00	1	5.00%	Very Good
19-24	0	0.00	16	80.00%	Good
13-18	4	20.00	3	15.00%	Fair
7-12	15	75.00	0	0.00%	Poor
1-6	1	5.00	0	0.00%	Very Poor
Total	20	100%	20	100%	

Table 1 outlines the achievements in the calculus of students before and after instruction for a controlled group subjected to traditional methods or direct instruction. Prior to the instruction, the majority of students (75%) scored within the 7-12 range, which falls under the "Poor" category. This indicates that a substantial portion of the class had limited calculus proficiency before receiving formal instruction. Additionally, 20% of the students scored in the 13-18 range, classified as "Fair," and a minimal 5% scored within the 1-6 range, labeled as "Very Poor." Notably, no students achieved scores within the higher brackets of 19-24 or 25-30, suggesting that none exhibited a "Good" or "Very Good" understanding of the material at the pre-test stage.

After the instructional period, the data reflects a significant shift in student performance. A remarkable 80% of the students scored within the 19-24 range, classified as "Good," demonstrating a notable increase in their calculus competence. Additionally, 5% of the students achieved scores in the 25-30 range, indicating a "Very Good" level of understanding. Conversely, the percentage of students in the "Fair" category dropped to 15%, with no students scoring in the "Poor" or "Very Poor" categories after instruction.

According to Giangan & Gurat (2022), students often struggle to grasp the mathematical concepts in calculus courses. This is particularly true for many undergraduate students, who view calculus as challenging and tend to misunderstand various topics. These results underscore the efficacy of direct instruction in enhancing students' calculus performance. The absence of students in the lower performance brackets post-instruction highlights the positive impact of the traditional teaching method on addressing learning gaps and elevating overall achievement levels (Abdulhameed & Al-Makahleh, 2011). The findings prove that traditional instructional approaches foster learning outcomes in foundational mathematical subjects.

Intervention Group

Table 2. Achievement in Calculus of Intervention Group

Scores	Pre-Test	%	Post-Test	%	Verbal Description
25-30	0	0.00	2	10%	Very Good
19-24	0	0.00	18	90%	Good
13-18	4	20.00	0	0%	Fair
7-12	16	80.00	0	0%	Poor
1-6	0	0.00	0	0%	Very Poor
Total	20	100%	20	100%	

Table 2 illustrates students' achievements in calculus before and after instruction for an intervention group using interactive teaching strategies. Before the intervention, 80% of students scored in the "Poor" category (7-12 range), while 20% scored in the "Fair" category (13-18 range). Notably, no students scored in the "Good" or "Very Good" categories during the pre-test phase, indicating limited initial understanding of the material.

Post-intervention, there was a marked improvement in student performance. A noteworthy 90% of the students scored within the "Good" range (19-24), while 10% achieved a "Very Good" rating (25-30 range). No students remained in the "Fair" or lower performance brackets, highlighting the effectiveness of interactive teaching strategies in fostering enhanced calculus comprehension.

Active learning is crucial in helping students comprehend mathematical concepts more effectively. Increasing students' interest in mathematics is key to enhancing their learning success. Incorporating real-life examples and encouraging independent problem-solving can increase engagement and highlight the real-world relevance of mathematical ideas (Hetmanenko, 2024). The study of Kamran et al. (2023) highlights the significance of integrating interactive teaching methods in higher education, offering valuable insights for educators to foster supportive and engaging learning environments. It underscores that effective implementation requires careful planning, skilled facilitation, and comprehensive training. The shift in scores underscores the positive impact of interactive teaching strategies on student achievement. By moving most students from lower performance categories to higher ones, the data suggests that engagement-driven methods can effectively close learning gaps and promote a deeper understanding of complex subjects.

Difference in the Pre-Test Scores between the Controlled and Intervention Group

Table 3. Difference in the pre-test scores of the controlled and intervention group

Group	Mean	SD	t-value	p-value	VD
Controlled	10.60	2.09	0.000	1.000	*Not Significant*

Intervention	10.60	2.06

Table 3 presents the difference in pre-test scores between the two groups. The control group (*M = 10.60, SD = 2.09)* and the intervention group *(M = 10.60, SD = 2.06)* performed similarly in the pre-test. The data indicates that the difference between the pre-test scores of the two groups was not statistically significant (*t = 0.000, p = 1.00*). Pre-tests are ungraded assessments used to evaluate students' existing knowledge of a subject. It is typically conducted before a course begins to establish a baseline understanding of the material (Berry, 2008). In addition, research indicates that administering pre-tests prior to instruction can enhance students' ability to learn and internalize key concepts introduced in later lessons (Janelli & Lipnevich, 2020). As a result, pre-tests contribute to a more efficient and personalized learning experience, fostering greater student engagement and improving overall learning outcomes. Additionally, these assessments can serve as a valuable diagnostic tool, guiding curriculum development and instructional design to ensure alignment with students' capabilities.

The lack of significant difference in pre-test scores suggests that both groups began the instructional period with similar levels of understanding and knowledge in differential calculus. This parity in baseline performance allows for a more accurate assessment of the effectiveness of the respective teaching strategies post-intervention. The findings support the validity of the comparative analysis by ensuring that any differences observed in post-test performance can be attributed to the instructional methods rather than initial disparities in student knowledge.

Difference in the Pre-Test and Post-Test Scores of the Controlled Group under Direct Instruction

Table 4. The difference in the achievement in calculus of students before and after direct instruction

Group	Mean	SD	t-value	p-value	Cohen's d	VD
Pre-test	10.6	2.09	-15.04	0.000	4.278	*Significantly Large Effect*
Post-test	20.6	2.14				

Table 4 presents the significant difference in calculus performance before and after direct instruction. The pre-test mean score was *M = 10.6* (*SD = 2.09*), while the post-test mean increased to *M = 20.6* (*SD = 2.14*). The results of the data analysis indicate that this improvement is statistically significant (*t = 15.04, p = .000*). Furthermore, Cohen's d of 4.278 reflects a significantly large effect size, suggesting a robust and meaningful difference between the pre-test and post-test results. The data demonstrates the substantial impact of direct instruction on student achievement in differential calculus. The large increase in mean scores and the significant effect size underscores the effectiveness of this instructional approach in enhancing students' understanding and performance. The results suggest that direct instruction improves knowledge retention and facilitates a more profound comprehension of calculus concepts.

Hermawan et al. (2020) describe direct instruction as a teaching approach where the teacher explains concepts or skills to students, followed by guided practice through exercises to reinforce understanding. Their findings suggest that direct instruction's structured and teacher-centered nature is particularly effective in mathematics, where step-by-step guidance can help students grasp complex procedures and concepts. It is also characterized by the teacher actively guiding students to recognize what they need to learn and how to apply this new knowledge effectively (Stockard, 2015). This method ensures that students clearly understand learning objectives and the practical use of acquired skills or concepts.

Difference in the Pre-Test and Post-Test Scores in the Experimental Group under Interactive Teaching Strategies

Table 5. The difference in the achievement in calculus of students before and after the interactive teaching strategies

Experimental	Mean	SD	t-value	p-value	Cohen's d	VD
Pre-test	10.60	2.06	-22.44	0.000	5.626	*Significantly Large Effect*
Post-test	22.05	2.01				

The results reveal a notable difference in student achievement after implementing interactive strategies. The pre-test mean score was *M = 10.60* (*SD = 2.06*), while the post-test mean score increased significantly to *M = 22.05* (*SD = 2.01*). The figures indicate that this improvement is statistically significant (*t = -22.44, p = .000*). Cohen's d value of 5.626 reflects a significantly large effect size, suggesting a substantial and meaningful difference between the pre-test and post-test scores. These findings highlight the considerable effectiveness of interactive teaching strategies in enhancing student learning and performance in differential calculus. The significant increase in mean scores and the large effect size underscores the transformative potential of engagement-driven instructional approaches.

Interactive strategies, which prioritize active student engagement and collaborative learning, have enhanced the understanding and retention of complex mathematical concepts (Munna & Kalam, 2021). Additionally, Jutin and Maat (2024) highlight that incorporating gamification into mathematics instruction improves student engagement, motivation, learning attitudes, and overall performance. Their findings suggest that gamification boosts cognitive skills and retention, nurtures social skills, fosters a positive learning environment, and helps alleviate math-related anxiety. The combination of interactive learning and gamification represents a powerful approach to teaching mathematics. These strategies address students' emotional and intellectual barriers by promoting hands-on experiences and creating an enjoyable, low-stress learning atmosphere.

Difference in the Achievements between the Two Groups of Students After the Instructions

Table 6. The difference in the achievements between the two groups of students after the instructions

Group	Mean	SD	t-value	p-value	VD
Controlled	20.60	2.14	-2.21	0.33	*Not Significant*
Intervention	22.05	2.01			

The study assesses the comparative effectiveness of direct instruction and interactive strategies in teaching differential calculus by examining the post-test achievements of the controlled and intervention groups. The results indicate that the controlled group achieved a post-test mean score of *M = 20.60 (SD = 2.14*), while the intervention group obtained a slightly higher mean score of *M = 22.05 (SD = 2.01).* A t-value of -2.21 and a p-value of 0.33 suggest that the observed difference in performance between the two groups is not statistically significant. Although the intervention group demonstrated marginally higher performance, the absence of a significant difference indicates that both instructional methods effectively contributed to student learning and achievement.

This suggests that while interactive strategies may offer slight improvements in engagement and conceptual understanding, direct instruction remains a viable and impactful teaching approach for differential calculus. The study of Alhaq, Nugraha, & Oding (2022) finds different results, which show that the cooperative learning model is more effective in enhancing student achievement than the direct instruction model. It demonstrates significant efficacy in facilitating the delivery of learning materials. Similarly, Tokac et al. (2018) meta-analysis indicates that game-based learning in mathematics contributed to slightly higher learning gains than traditional instructional methods. Meanwhile, Oladayo & Oladayo (2012) revealed that the direct instructional strategy has a more significant impact on students' Mathematics achievement than the indirect instructional strategy. Both types of instruction offer distinct benefits; however, the students in this action research study showed greater improvement with direct instruction than with interactive instruction (Connell, 2012). This outcome highlights the potential value of combining the two approaches to address diverse learning needs, leveraging the structured delivery of direct instruction alongside the engagement and collaboration fostered by interactive strategies.

Students Attitude in the Interactive Strategies in Differential Calculus

Table 7. Students Attitude in the Implementation of Interactive Teaching Strategies

Attitudinal Questions	Mean	Verbal Description
1. The interactive teaching methods effectively clarified the fundamental concepts of basic rules and higher-order derivatives in differential calculus.	3.70	Very Positive
2. The instructor effectively utilized interactive teaching methods to encourage student participation and discussion.	3.70	Very Positive
3. The interactive teaching approach helps apply differential calculus principles to solve problems.	3.60	Very Positive
4. I feel more confident applying differential calculus concepts after participating in interactive teaching sessions.	3.40	Very Positive
5. The interactive teaching sessions effectively clarified complex topics and made them easier for me to understand.	3.10	Positive
6. The interactive teaching approach helped me develop problem-solving skills specific to differential calculus.	2.95	Positive
7. The interactive teaching methods were motivating and conducive to my learning experience.	3.65	Very Positive
8. The collaborative learning environment fostered by interactive activities improved my learning outcomes in differential calculus.	3.50	Very Positive
9. The interactive teaching approach encouraged critical thinking and problem-solving skills development.	3.65	Very Positive
10. Overall, I am satisfied with the effectiveness of interactive teaching in the differential calculus courses.	3.60	Very Positive
Overall Mean	**3.50**	**Very Positive**

The study investigates students' perceptions of interactive strategies in teaching differential calculus through attitudinal questions measuring various aspects of the learning experience. Table 7 reveals that students responded positively to using interactive teaching methods, with an overall mean score of 3.50, indicating a "Very Positive" perception. Specifically, the highest-rated aspects *(M = 3.70)* include the effectiveness of interactive methods in clarifying fundamental concepts and encouraging participation and discussion. Similarly, students found the methods helpful in problem-solving *(M = 3.60)* and motivating *(M = 3.65),* further reinforcing the benefits of active engagement in the learning process.

Additionally, students expressed increased confidence in applying differential calculus concepts *(M = 3.40)* and acknowledged the role of collaborative learning in enhancing outcomes *(M = 3.50).* Although the development of problem-solving skills scored slightly lower *(M = 2.95)*, it still reflects a "Positive" evaluation. According to Yusufjanovna (2023), interactive mathematics learning can capture students' attention and foster active participation in the classroom. Moreover, it can enhance the learning experience by making mathematics more engaging and enjoyable. Active learning is an effective teaching strategy for positively influencing students' attitudes toward mathematics. By actively engaging students in the learning process, this approach fosters a deeper understanding and appreciation of the subject (Kazmagambet et al., 2020). The data suggest that interactive strategies improve conceptual understanding and foster a conducive learning environment that enhances critical thinking and motivation. These findings align with previous research indicating the effectiveness of student-centered learning approaches in mathematics education. Overall, the study highlights the importance of incorporating interactive methods to optimize learning outcomes in differential calculus courses.

Implications of the Study to the Teaching and Learning of Mathematics

The study's findings suggest that interactive teaching strategies can positively influence students' achievement in calculus, as reflected in the intervention group's significant improvement in post-test scores. This implies that incorporating student-centered methods—such as collaborative activities, guided inquiry, and the use of interactive tools—can enhance conceptual understanding and engagement in mathematics. The favorable attitudes expressed by students further indicate that such strategies may contribute to a more supportive and motivating learning environment. While the results do not dismiss the value of traditional approaches, they highlight the potential of interactive methods to complement and strengthen mathematics instruction, particularly in complex subjects like calculus. These findings encourage educators to integrate varied instructional techniques promoting active learning and deeper student participation.

CONCLUSIONS AND RECOMMENDATIONS

The findings of this study provide significant insights into the effectiveness of both direct instruction and interactive teaching strategies in improving students' achievement in differential calculus. The pre-test results revealed no statistically significant difference in the baseline performance of the controlled and intervention groups, indicating that both groups began with comparable levels of understanding.

A substantial improvement was observed for the control group, which underwent traditional direct instruction. Most students initially scored poorly, but post-test results showed a remarkable shift, with most of the students achieving good scores. These results underscore the impact of structured and explicit teaching methods in enhancing student performance and comprehension. Similarly, the intervention group, which was taught using interactive teaching strategies, significantly improved. While most of the students initially achieved poorly in the pre-test, post-intervention results demonstrated a notable increase in achievement, corroborated by a large effect size. Furthermore, students in this group reported a positive perception of the interactive approach, highlighting its role in fostering a conducive learning environment, enhancing motivation, and improving attitudes toward calculus.

Although the intervention group demonstrated marginally higher post-test performance, the absence of a statistically significant difference between the two groups suggests that both instructional strategies effectively improve student achievement. Direct instruction remains a viable and impactful approach for teaching differential calculus, particularly for ensuring foundational competence. However, interactive strategy, emphasizing engagement and conceptual understanding, shows promise for fostering positive student attitudes and sustained motivation. In conclusion, both teaching strategies hold transformative potential in differential calculus education, with direct instruction excelling in structured skill-building and interactive methods enhancing student engagement and perceptions. Educators may consider a blended approach to maximize performance outcomes and the learning experience.

However, the study is not without limitations. The small sample size and single-institution context may limit the generalizability of findings. The short duration of the intervention may not fully capture the long-term effects of the strategies employed. Furthermore, qualitative insights were limited to attitudinal surveys, lacking in-depth interviews or classroom observations that could offer richer perspectives.

FURTHER STUDY

Future researchers are encouraged to conduct longitudinal studies with larger and more diverse populations, integrate mixed-method designs, and explore subject-specific interactive strategies tailored to different mathematical topics for more nuanced insights.

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