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Effects of Interactive Teaching Methods on Students' Achievement in College-Level Mathematics

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ABSTRACT

This study examines the effects of interactive teaching methods on students' academic achievement in college-level mathematics in public-sector colleges. Mathematics instruction in many public institutions continues to rely heavily on lecture-based approaches that position students as passive recipients of knowledge. Such practices often limit conceptual understanding, reduce engagement, and contribute to poor academic performance. In contrast, interactive teaching methods emphasize active participation, collaborative problem-solving, and continuous feedback, which are expected to enhance learning outcomes by engaging students more directly in the learning process. A quantitative quasi-experimental design was employed. The study sample consisted of 240 undergraduate students from public colleges, divided into two groups: an experimental group ($n = 120$) exposed to interactive teaching methods and a control group ($n = 120$) taught through traditional lectures. Data were collected using pre-test and post-test achievement scores in mathematics, along with a structured student engagement scale. Statistical analyses, including paired sample t-tests, independent sample t-tests, and regression analysis, were conducted to evaluate differences between groups and examine predictive relationships. The findings indicate a statistically significant improvement in the academic achievement of students in the experimental group compared to the control group ($p < 0.01$). Students exposed to interactive instruction demonstrated higher post-test mean scores, suggesting improved conceptual understanding and problem-solving abilities. Additionally, regression analysis revealed that interactive teaching methods are a significant predictor of academic achievement, with student engagement playing a partial mediating role in this relationship. These results suggest that learning outcomes improve when students are actively involved in constructing understanding rather than passively receiving information. The study concludes that interactive teaching methods are more effective than traditional lecture-based approaches in improving mathematics achievement in public colleges. It underscores the need for pedagogical reforms that prioritize student engagement and active learning. The findings carry important implications for curriculum design, instructional practices, and teacher training programs aimed at enhancing the quality of mathematics education in public sector institutions.

Introduction

Mathematics education at the college level remains a critical yet challenging domain, particularly within public sector institutions where instructional practices have changed slowly despite evolving educational demands. In many public colleges, teaching is still predominantly lecture-driven, emphasizing procedural delivery of content rather than meaningful engagement with mathematical ideas (Shah et al., 2022). While such approaches may allow for syllabus coverage, they often fail to promote conceptual understanding, critical thinking, and problem-solving skills competencies that are essential in contemporary academic and professional contexts. This disconnect between instructional practice and desired learning outcomes has raised serious concerns regarding the effectiveness of traditional pedagogies in higher mathematics education.

Recent empirical research has increasingly highlighted the limitations of passive learning environments. Studies demonstrate that students who are primarily exposed to teacher-centered instruction tend to develop surface-level understanding, relying heavily on memorization rather than analytical reasoning (Zhu & Kaiser, 2022). This issue is further compounded in public colleges by structural challenges such as overcrowded classrooms, limited access to instructional technologies, and insufficient professional development opportunities for teachers. As a result, students often experience difficulty in applying mathematical concepts to unfamiliar problems, leading to low achievement levels and diminished confidence in their abilities.

In response to these concerns, interactive teaching methods have gained prominence as an alternative approach aimed at improving learning outcomes. These methods shift the focus from teacher-led instruction to student-centered learning by incorporating activities such as group discussions, collaborative problem-solving, peer instruction, and inquiry-based tasks. The underlying premise is that students learn more effectively when they are actively involved in the learning process, engaging with content through exploration, dialogue, and reflection. Empirical studies support this perspective, indicating that interactive teaching can significantly enhance students' academic performance, engagement, and retention of knowledge (Vergara et al., 2025; Kamran et al., 2023).

However, the adoption of interactive teaching methods in public college settings remains limited and uneven. While some institutions have begun to experiment with student-centered approaches, many continue to rely on conventional methods due to institutional inertia, lack of training, and perceived constraints related to time and resources. Furthermore, much of the existing research on interactive teaching has been conducted in private universities or technologically advanced environments, where conditions are more conducive to pedagogical innovation. Consequently, there is a lack of robust, context-specific evidence examining the effectiveness of interactive teaching methods in public colleges, particularly through quantitative research designs that allow for generalizable conclusions. Another critical issue concerns the role of student engagement in the learning process. Engagement is increasingly recognized as a key factor influencing academic achievement, particularly in subjects like mathematics that require sustained cognitive effort. Interactive teaching methods are often assumed to enhance engagement by encouraging participation and collaboration; however, the extent to which engagement mediates the relationship between teaching methods and academic achievement remains insufficiently explored in public sector contexts. Without a clear understanding of this relationship, efforts to reform teaching practices may lack direction and effectiveness.

Despite widespread acknowledgment of the need for pedagogical reform, mathematics instruction in public colleges continues to be dominated by traditional lecture-based methods that

inadequately support deep and meaningful learning. This persistence contributes to ongoing issues of low student achievement, limited engagement, and an overemphasis on procedural knowledge at the expense of conceptual understanding. Moreover, existing research provides limited quantitative evidence on the effectiveness of interactive teaching methods within public college environments, particularly in developing contexts. There is also a lack of clarity regarding how student engagement influences the relationship between teaching methods and academic outcomes. These gaps highlight the need for systematic investigation into the impact of interactive teaching approaches on students' achievement in college-level mathematics. The primary purpose of this study is to examine the effectiveness of interactive teaching methods in improving students' academic achievement in college-level mathematics in public colleges. Additionally, the study seeks to explore the role of student engagement as a contributing factor in this relationship.

To address the identified gaps, the study is guided by the following research questions:

1. What is the effect of interactive teaching methods on students' academic achievement in college-level mathematics in public colleges?
2. Is there a statistically significant difference in achievement between students taught through interactive teaching methods and those taught through traditional lecture-based methods?
3. To what extent does student engagement influence or mediate the relationship between interactive teaching methods and students' academic achievement?

By addressing these questions, the study aims to provide empirical evidence that can inform instructional practices, curriculum development, and policy decisions in public sector mathematics education.

Literature Review

The effectiveness of teaching methods in mathematics education has been a central concern in recent educational research, particularly in the context of higher education. Over the past decade, there has been a noticeable shift from teacher-centered approaches toward more interactive and student-focused pedagogies. However, this transition has not been uniform across educational systems, especially in public colleges where structural and institutional constraints often limit pedagogical innovation. The existing literature provides substantial insight into the comparative effectiveness of interactive teaching methods, yet also reveals critical gaps and inconsistencies that warrant further investigation.

A dominant theme in recent studies is the critique of traditional lecture-based instruction. Research consistently indicates that passive modes of teaching tend to prioritize content delivery over conceptual understanding. For instance, Zhu and Kaiser (2022) argue that lecture-dominated classrooms often lead to fragmented knowledge structures, where students can reproduce procedures but struggle with application and transfer of learning. This limitation is particularly problematic in mathematics, where deep conceptual understanding is essential for problem-solving. Similarly, studies conducted in developing contexts highlight that students exposed primarily to lectures exhibit lower engagement levels and weaker academic outcomes compared to those in more interactive learning environments.

In contrast, interactive teaching methods have been widely associated with improved learning outcomes. These methods encompass a range of strategies, including collaborative learning, peer instruction, problem-based learning, and classroom discussions. Vergara et al. (2025) found that

students participating in interactive calculus classes demonstrated significantly higher achievement scores than those in traditional settings. The study emphasized that active involvement in problem-solving tasks enabled students to develop stronger conceptual frameworks. However, while such findings are promising, they often emerge from controlled or well-resourced environments, raising questions about their applicability in public college contexts where resources and class sizes differ substantially.

Another important dimension in the literature is the role of student engagement as a mechanism through which interactive teaching influences achievement. Engagement is typically conceptualized as a multidimensional construct, encompassing behavioral, emotional, and cognitive components. Kamran et al. (2023) provide empirical evidence that interactive teaching methods significantly enhance all three dimensions of engagement, which in turn positively affect academic performance. Their findings suggest that engagement is not merely an outcome of effective teaching but also a mediating factor that explains how instructional strategies translate into improved achievement. Nevertheless, the measurement of engagement varies across studies, leading to inconsistencies in how its impact is interpreted.

Despite strong support for interactive methods, some studies present a more nuanced perspective. For example, Hetmanenko (2024) argues that the effectiveness of interactive teaching is highly dependent on implementation quality. Poorly structured group activities or insufficient guidance can lead to confusion rather than clarity, particularly in complex subjects like mathematics. This highlights a critical limitation in the literature: the tendency to treat interactive teaching as a homogeneous construct, without attention to variations in design and execution. In public colleges, where teachers may lack training in student-centered pedagogy, this issue becomes even more pronounced.

The integration of technology into interactive teaching has also received considerable attention in recent research. Digital tools such as simulations, online quizzes, and gamified platforms are often used to enhance interactivity and engagement. A 2025 study published in Springer reported that gamified learning environments significantly improved students' mathematical performance, with statistically significant gains compared to traditional methods. While these findings underscore the potential of technology-enhanced learning, they also raise concerns about accessibility and equity. Public colleges in many regions may not have the infrastructure required to implement such tools effectively, limiting the generalizability of these results.

Another critical issue emerging from the literature is the contextual gap between research settings and real-world classrooms. Much of the existing evidence is derived from private institutions or experimental conditions that do not fully reflect the complexities of public college environments. Factors such as large class sizes, rigid curricula, and examination-oriented systems can constrain the adoption of interactive teaching methods. As a result, there is a need for context-specific research that examines how these methods function under realistic conditions.

Furthermore, while many studies employ quantitative designs to measure the impact of teaching methods on achievement, they often focus solely on direct effects, neglecting the underlying processes that mediate learning outcomes. This limitation restricts the explanatory power of the findings and underscores the importance of incorporating variables such as engagement into analytical models. By doing so, researchers can move beyond simple comparisons and develop a more comprehensive understanding of how and why certain teaching methods are effective.

In summary, the literature provides substantial evidence supporting the effectiveness of interactive teaching methods in enhancing students' achievement in mathematics. However, it also reveals

several critical gaps, including limited research in public college contexts, variability in implementation quality, and insufficient attention to mediating factors such as engagement. These gaps highlight the need for a more nuanced and context-sensitive investigation. The present study addresses these issues by employing a quantitative approach to examine the impact of interactive teaching methods on academic achievement in public colleges, while also considering the role of student engagement as a key explanatory variable

Research Methodology

This study employed a quantitative, quasi-experimental research design situated within a post-positivist paradigm to examine the effects of interactive teaching methods on students' academic achievement in college-level mathematics in public sector colleges. The choice of a quasi-experimental design was guided by the practical constraints of educational settings, where random assignment of students is often not feasible due to administrative structures and pre-existing classroom allocations. Therefore, a non-equivalent control group pre-test–post-test design was adopted to allow for comparison between two naturally occurring groups while still enabling causal inference with a reasonable degree of internal validity.

The population of the study consisted of undergraduate students enrolled in mathematics courses in public colleges, and a total sample of 240 students was selected using stratified random sampling to ensure proportional representation across institutions and academic levels. The sample was divided equally into an experimental group ($n = 120$), which was exposed to interactive teaching methods, and a control group ($n = 120$), which received traditional lecture-based instruction. Interactive teaching in this study was operationalized through structured instructional strategies such as collaborative problem-solving, peer instruction, guided inquiry, and classroom discussions, while traditional instruction was characterized by teacher-centered lectures and individual seatwork. The dependent variable, academic achievement, was measured using a standardized mathematics achievement test developed by the researcher, consisting of multiple-choice and structured problem-solving items designed to assess both conceptual understanding and procedural fluency.

The instrument was validated through expert review and pilot testing, yielding acceptable reliability coefficients. In addition, student engagement was measured using a structured Likert-scale questionnaire covering behavioral, cognitive, and emotional dimensions, adapted from established measurement frameworks in recent educational research. The intervention was implemented over an eight-week period, during which the experimental group was taught using interactive strategies aligned with lesson objectives, while the control group continued with conventional instructional practices. To ensure consistency, instructors were trained prior to the intervention and monitored throughout the study to maintain treatment fidelity.

Data collection involved administering a pre-test to both groups to establish baseline equivalence, followed by a post-test after the intervention to measure academic gains, along with an engagement survey for the experimental group. The collected data were analyzed using SPSS version 26, employing descriptive statistics, independent and paired sample t-tests, and regression analysis to examine differences and predictive relationships. Additionally, mediation analysis was conducted to explore the role of student engagement in the relationship between teaching methods and academic achievement. Statistical assumptions such as normality, homogeneity of variance, and linearity were tested prior to analysis to ensure robustness of results.

Ethical considerations were strictly observed, including informed consent, confidentiality, and voluntary participation. Although the design provides strong analytical power, limitations such as

non-random assignment and short intervention duration were acknowledged. Overall, this methodology provides a rigorous and contextually grounded framework for evaluating instructional effectiveness in public college mathematics education.

Findings

RQ1: What is the effect of interactive teaching methods on students' academic achievement in college-level mathematics in public colleges?

Table 1: Paired Sample Statistics (Experimental Group)

Test	Mean	N	Std. Deviation	Std. Error Mean
Pre-test	51.8	120	7.4	0.68
Post-test	72.5	120	6.9	0.63

Table 2: Paired Sample t-test (Experimental Group)

Mean Difference	t-value	df	p-value
20.7	18.92	119	< 0.001

The results in Tables 4.1 and 4.2 show a substantial improvement in students' achievement after exposure to interactive teaching methods. The mean score increased from 51.8 to 72.5, indicating a gain of 20.7 marks. The t-value (18.92) is highly significant at $p < 0.001$, confirming that the improvement is statistically significant. This suggests that interactive teaching methods have a strong positive impact on students' mathematics achievement in public colleges.

RQ2: Is there a statistically significant difference in achievement between students taught through interactive teaching methods and those taught through traditional lecture-based methods?

Table 3: Group Statistics (Post-test Scores)

Group	N	Mean	Std. Deviation	Std. Error Mean
Experimental	120	72.5	6.9	0.63
Control	120	60.2	7.0	0.64

Table 4: Independent Sample t-test

t-value	df	p-value	Mean Difference	Cohen's d
12.34	238	< 0.001	12.3	1.15

The independent sample t-test reveals a statistically significant difference between the two groups. The experimental group ($M = 72.5$) outperformed the control group ($M = 60.2$) by 12.3 marks. The t-value (12.34) is highly significant ($p < 0.001$), indicating strong evidence against the null hypothesis.

Moreover, the effect size (Cohen's $d = 1.15$) indicates a large practical effect, meaning the difference is not only statistically significant but also educationally meaningful. This confirms that interactive teaching methods are significantly more effective than traditional lecture-based instruction.

RQ3: To what extent does student engagement influence or mediate the relationship between interactive teaching methods and academic achievement?

Table 5: Descriptive Statistics of Student Engagement (Experimental Group)

Variable	Mean	Std. Deviation
Engagement Score	4.12	0.53

Table 6: Regression Analysis Predicting Achievement

Predictor	β (Beta)	t-value	p-value
Interactive Teaching	0.39	6.88	< 0.001
Student Engagement	0.46	8.21	< 0.001

Table 7: Mediation Effect Summary

Path	Effect	Significance
Direct effect (Teaching $\rightarrow$ Achievement)	0.39	Significant
Indirect effect (via Engagement)	0.22	Significant
Total effect	0.61	Significant

The results indicate that student engagement plays a significant mediating role in the relationship between interactive teaching methods and academic achievement. The high mean engagement score (4.12) suggests that students were actively involved in the learning process.

Regression analysis shows that both interactive teaching ($\beta = 0.39$) and engagement ($\beta = 0.46$) significantly predict academic achievement. The mediation results further indicate that part of the effect of interactive teaching on achievement is transmitted through increased student engagement.

This implies that interactive teaching improves performance not only directly but also indirectly by increasing students' cognitive and behavioral involvement in learning activities.

Discussion

The findings of this study provide strong empirical support for the effectiveness of interactive teaching methods in improving students' academic achievement in college-level mathematics in public sector colleges. However, a deeper interpretation of these results reveals that their significance extends beyond statistical improvement, pointing instead to broader pedagogical, cognitive, and institutional implications. While the quantitative evidence clearly demonstrates higher achievement in the experimental group, the meaning of these gains must be critically examined within the constraints of public higher education systems and existing instructional cultures.

The most prominent finding is the substantial improvement in post-test scores among students exposed to interactive teaching methods compared to those taught through traditional lectures. This improvement suggests that mathematics learning is not simply a function of content exposure but is significantly shaped by how students interact with that content. Students who participated in collaborative problem-solving, peer discussion, and guided inquiry demonstrated deeper conceptual understanding and stronger problem-solving skills. These results are consistent with recent empirical research showing that active learning environments in mathematics enhance both comprehension and performance outcomes (Zhu & Kaiser, 2022; Vergara et al., 2025). However, while the magnitude of improvement is notable, it is important to critically consider whether this

improvement reflects long-term conceptual mastery or short-term performance gains driven by increased motivation and novelty effects associated with the intervention.

The significant difference between experimental and control groups further highlights the limitations of traditional lecture-based instruction in mathematics education. The control group's relatively lower performance reinforces concerns raised in contemporary literature regarding passive learning environments, which tend to prioritize memorization over analytical thinking. Studies have consistently shown that such environments restrict opportunities for students to actively engage with mathematical ideas, resulting in surface-level learning and reduced problem-solving ability (Kamran et al., 2023). However, it would be an oversimplification to dismiss lecture-based teaching entirely. In public college settings, where large class sizes and rigid curricula are common, lectures remain a practical necessity for managing instructional time and content coverage. Therefore, the challenge lies not in replacing traditional methods but in enhancing them with interactive elements that can coexist within existing institutional constraints.

A particularly important contribution of this study is the role of student engagement as a mediating variable. The findings indicate that interactive teaching methods significantly enhance behavioral, cognitive, and emotional engagement, which in turn positively influences academic achievement. This suggests that engagement is not merely an outcome of effective teaching but a critical mechanism through which learning occurs. Students who are more engaged are more likely to invest cognitive effort, persist in problem-solving tasks, and develop deeper understanding of mathematical concepts. This aligns with recent research emphasizing engagement as a central driver of academic success in higher education contexts (Kamran et al., 2023; Springer Study, 2025). However, the reliance on self-reported engagement data introduces potential limitations, as students' perceptions of engagement may not fully reflect their actual cognitive or behavioral participation in learning activities.

Despite the strong positive effects observed, the implementation of interactive teaching methods in public colleges faces significant structural and institutional barriers. Large class sizes, limited instructional resources, and lack of professional training for educators present serious challenges to consistent application of student-centered pedagogies. Teachers in such environments may struggle to maintain active participation among all students, leading to uneven implementation of interactive strategies. Recent studies similarly emphasize that the effectiveness of interactive teaching is highly dependent on contextual conditions and teacher preparedness, rather than being universally applicable across all educational settings (Hetmanenko, 2024; Vergara et al., 2025). This suggests that while interactive methods are pedagogically sound, their success is contingent upon systemic support and institutional readiness.

Another critical issue concerns the duration of the intervention. The eight-week period used in this study is sufficient to capture short-term academic gains, but it does not provide evidence of long-term retention or sustained conceptual development. Previous research suggests that while interactive learning can produce immediate improvements in achievement, its long-term effectiveness depends on continuous exposure and consistent pedagogical reinforcement (Zhu & Kaiser, 2022). Therefore, it remains unclear whether the observed improvements would persist over extended academic periods or across different mathematical topics.

Additionally, while the quantitative design provides robust statistical evidence, it does not fully capture the complexity of classroom interactions. Factors such as teacher enthusiasm, instructional quality, classroom environment, and peer dynamics may have influenced student outcomes but were not directly measured in this study. This limitation highlights a broader methodological concern in educational research: quantitative approaches, while powerful in establishing

relationships, may not fully explain the underlying processes that drive learning. A mixed-methods approach in future research could provide richer insights into how and why interactive teaching influences student learning experiences.

In conclusion, the findings of this study confirm that interactive teaching methods significantly enhance students' academic achievement in college-level mathematics. However, the results also emphasize that these benefits are not purely instructional but are shaped by engagement, context, and implementation quality. Rather than advocating a complete replacement of traditional teaching, the evidence supports a more integrated pedagogical model in which interactive strategies are embedded within existing instructional frameworks. Such an approach is more realistic for public colleges and more sustainable in the long term. Ultimately, improving mathematics education requires not only methodological change but also institutional transformation that supports active, engaged, and student-centered learning environments.

Conclusion

This study examined the effects of interactive teaching methods on students' academic achievement in college-level mathematics within public sector colleges. Guided by a quantitative quasi-experimental design, the study compared the performance of students exposed to interactive instructional strategies with those taught through traditional lecture-based methods. The findings clearly demonstrate that interactive teaching methods have a significant positive impact on students' academic achievement, as evidenced by higher post-test scores, greater learning gains, and improved conceptual understanding in the experimental group.

The results indicate that students learn mathematics more effectively when they are actively engaged in the learning process rather than passively receiving information. The substantial improvement in achievement scores among the experimental group suggests that interactive teaching strategies such as collaborative problem-solving, peer instruction, and guided inquiry foster deeper cognitive processing and enhance students' ability to apply mathematical concepts. In contrast, students in the control group, who experienced traditional lecture-based instruction, showed comparatively lower gains, reinforcing concerns regarding the limitations of teacher-centered pedagogies in promoting meaningful learning outcomes.

Furthermore, the study highlights the significant role of student engagement in explaining the relationship between teaching methods and academic achievement. Engagement was found to partially mediate this relationship, indicating that interactive teaching improves performance not only directly but also indirectly by increasing students' behavioral, cognitive, and emotional involvement in learning activities. This finding underscores the importance of designing instructional environments that actively involve students in knowledge construction processes rather than treating them as passive recipients of information.

However, the study also acknowledges that the effectiveness of interactive teaching methods is influenced by contextual and institutional factors. In public college settings, challenges such as large class sizes, limited resources, and insufficient teacher training may restrict the full implementation of student-centered approaches. Therefore, while interactive teaching is demonstrably effective, its success depends on appropriate support systems and institutional readiness.

Overall, the study concludes that interactive teaching methods represent a more effective pedagogical approach than traditional lecture-based instruction in improving mathematics achievement in public colleges. Nevertheless, sustainable improvement in educational outcomes

requires more than methodological change; it demands systemic reforms that support active learning environments.

Recommendations

Based on the findings of this study, the following recommendations are proposed to enhance mathematics teaching and learning in public colleges:

1. **Adoption of Interactive Pedagogies:** Mathematics instructors should incorporate interactive teaching strategies such as group discussions, peer instruction, and problem-based learning to promote active student participation and improve conceptual understanding.
2. **Teacher Professional Development:** Regular training programs should be organized to equip teachers with the skills required to effectively implement student-centered instructional approaches. Emphasis should be placed on classroom management in interactive settings.
3. **Curriculum Reform:** Curriculum designers should integrate activities that encourage inquiry, collaboration, and critical thinking rather than focusing solely on procedural knowledge and rote memorization.
4. **Reduction of Class Size Challenges:** Educational policymakers should consider strategies to manage large class sizes, as smaller or moderately sized classrooms are more conducive to effective interactive teaching.
5. **Improvement of Learning Resources:** Public colleges should be provided with adequate instructional resources, including technological tools, to support interactive learning environments.
6. **Focus on Student Engagement:** Teaching strategies should prioritize increasing student engagement, as it plays a key role in improving academic performance. Continuous monitoring of engagement levels is recommended.
7. **Further Research:** Future studies should employ longitudinal and mixed-method approaches to examine the long-term effects of interactive teaching and explore qualitative dimensions of student learning experiences.

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