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Original Article

Enhancing Students' Academic Performance in Basic Calculus Through Reciprocal Peer Tutoring

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Abstract. This study addressed the need for effective instructional strategies to improve students' performance in basic calculus, particularly in topics such as limits and derivatives. It aimed to examine the effectiveness of Reciprocal Peer Tutoring (RPT) among Grade 11 STEM students. A quasi-experimental pretest–posttest control group design was employed involving seventy-eight (78) students, with 38 assigned to the experimental group and 40 to the control group. A researcher-developed, validated, and reliable 40-item multiple-choice test was used to measure students' performance before and after the intervention. Descriptive results indicated that the experimental group (M = 14.95, SD = 4.08) and control group *(M = 14.15, SD = 4.21)* had comparable pretest scores. An analysis of covariance (ANCOVA) was conducted to examine differences in posttest performance while controlling for pretest scores. Results showed that pretest scores were significantly associated with posttest performance, $F(1, 75) = 100.84$, $p < .001$, partial $\eta^2 = .57$. After adjustment, a statistically significant difference in posttest scores was found between the experimental and control groups, $F(1, 75) = 152.92$, $p < .001$, partial $\eta^2 = .67$, with the experimental group obtaining higher mean scores. These findings suggest that reciprocal peer tutoring may support improved academic performance in basic calculus. The study concludes that structured peer-assisted learning can serve as a useful complementary instructional approach within similar classroom contexts.

Keywords: *Academic performance; Basic calculus; Reciprocal peer tutoring; Senior high school students; STEM.*

Mathematics plays a vital role in developing students' analytical thinking, logical reasoning, and problem-solving skills. Within the senior high school curriculum, Basic Calculus serves as a critical bridge between elementary mathematics and advanced studies in Science, Technology, Engineering, and Mathematics (STEM). It improves students' capacity to think abstractly, analyze quantitatively, and solve real-world problems. Despite its importance, Basic Calculus is widely regarded as one of the most challenging subjects for students due to its abstract nature and high cognitive demands (Díaz-Chang & Hernández-Arredondo, 2024).

Research has consistently shown that students encounter significant conceptual difficulties in fundamental calculus topics such as limits, continuity, and derivatives, which often lead to low academic performance (Areaya & Sidelil, 2021). These difficulties are further compounded by insufficient prerequisite knowledge and persistent

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misconceptions, particularly in applying rules of differentiation (Machaba & Fasinu, 2024). In the local context, a study conducted in Davao de Oro revealed that students struggled with the least learned calculus competencies, highlighting the need for targeted instructional interventions to support conceptual understanding (Hernane et al., 2025). These findings suggest that challenges in learning Basic Calculus are not only conceptual but also instructional in nature.

Traditional teacher-centered approaches remain prevalent in mathematics classrooms; however, such approaches may limit student engagement, interaction, and active participation in the learning process. In such environments, students often become passive recipients of knowledge, which can hinder meaningful learning and fail to address differences in prior knowledge, learning needs, and pacing. As a result, there is a growing need for learner-centered instructional strategies that promote collaboration, engagement, and deeper conceptual understanding (Freeman et al., 2014).

Reciprocal Peer Tutoring (RPT) is a systematic form of peer-assisted learning in which students take turns as tutors and tutees. This technique promotes active engagement, the exposition of concepts, and collaborative problem-solving. Previous research has shown that RPT enhances students' mathematical understanding, confidence, and academic achievement in courses such as General Mathematics, particularly those involving algebraic manipulation, functions, and trigonometric relationships (Celedonio & Elicay, 2024). Similarly, in Physics, RPT has been proven to improve students' performance in solving issues involving motion, formula, and quantitative connections (Oludipe, 2009). Based on social constructivist theory, RPT emphasizes that learning occurs through interaction, conversation, and the creation of shared knowledge, enabling students to clarify misconceptions and deepen their understanding through peer explanation (Talkhan et al., 2025).

However, despite the established effectiveness of Reciprocal Peer Tutoring in these subject areas, there remains a significant gap in its application to senior high school Basic Calculus. While prior studies in General Mathematics and Physics primarily involve procedural and formula-based problem-solving, Basic Calculus presents a distinct challenge because it introduces students to abstract concepts such as limits and derivatives, which require deeper conceptual understanding rather than routine computation. Moreover, existing research on calculus instruction is largely concentrated at the college level, with limited attention given to how senior high school students develop understanding during their initial exposure to calculus concepts. Specifically, there is insufficient empirical evidence on how Reciprocal Peer Tutoring supports students in overcoming conceptual difficulties in limits and derivatives at the secondary level.

In response to this gap, this study aims to examine the effectiveness of Reciprocal Peer Tutoring (RPT) in improving the academic performance of senior high school students in Basic Calculus. By focusing on foundational topics such as limits and derivatives, this study extends the application of peer-assisted learning to a previously underexamined context. It provides empirical evidence on how collaborative learning strategies can address persistent conceptual difficulties in calculus.

Methodology

Research Design

The study employed a pretest–posttest control-group quasi-experimental research design to assess the effectiveness of Reciprocal Peer Tutoring in improving the academic performance of Grade 11 STEM students in Basic Calculus. This design involved two groups: an experimental group that received the intervention and a control group that underwent conventional instruction. The use of pre- and post-test measures allowed comparison of students' performance before and after the intervention.

A quasi-experimental approach was adopted because random assignment of participants was not feasible, as the students were organized into intact class sections. This design is appropriate for educational research conducted in natural classroom settings where full randomization is not possible. The inclusion of a control group enabled comparison, allowing the researcher to determine whether changes in academic performance could be attributed to the intervention (Creswell & Creswell, 2018).

Participants and Sampling Technique

The participants of the study were seventy-eight (78) Grade 11 STEM students selected using cluster sampling, wherein intact class sections served as the sampling units. Two Grade 11 STEM sections from Matanao 1 District

were selected to participate in the study. These sections, identified as STEM 1 and STEM 2, comprised the participants of the study. Following the selection of the clusters, random assignment at the group level was employed to determine which section would receive the intervention. Through randomization, one section was assigned to the experimental group and received instruction through Reciprocal Peer Tutoring, while the other was designated the control group and taught using conventional instruction. This approach ensured that each class section had an equal chance of being assigned to either condition. Participants included in the study were those officially enrolled in the Grade 11 STEM strand and regularly attending Basic Calculus classes. Students who were absent during the intervention period or did not participate in the instructional sessions were excluded to ensure consistency in the data collected.

Research Instrument

This study employed a researcher-developed achievement test to measure students' academic performance in Basic Calculus. The instrument consisted of forty (40) multiple-choice items covering fundamental topics, particularly limits and derivatives. The test was constructed in accordance with the Most Essential Learning Competencies (MELCs) prescribed by the Department of Education. A Table of Specifications (TOS) was developed to ensure alignment between the test items, targeted competencies, and cognitive process levels, establishing adequate content representation and balance. The initial pool of 50 items was drafted based on the MELCs and TOS, with each item written to assess a specific competency. Items were reviewed for clarity and content accuracy before expert validation. After expert feedback and pilot testing, 10 items were revised or removed, resulting in the final 40-item test.

Content validity of the instrument was established through expert evaluation. Four (4) experienced Basic Calculus teachers, each with three to five years of teaching experience, assessed the test in terms of clarity, relevance, and organization using established validation criteria (Nurdin, 2007, as cited in Taherdoost, 2018). The instrument obtained an overall mean rating of 4.39, which indicates a high level of content validity and supports its suitability for measuring the intended learning outcomes.

A pilot test was conducted among thirty (30) students with characteristics comparable to the actual participants, but who were not included in the main study. Item analysis was performed to evaluate item difficulty and discrimination indices. The average item difficulty index was 0.58, and the average discrimination index was 0.41, indicating moderately appropriate difficulty and good discriminating power. Items identified as having poor discrimination (below 0.20) or extreme difficulty levels (below 0.30 or above 0.80) were revised or replaced to enhance the overall quality of the instrument. The internal consistency reliability of the test was determined using the Kuder–Richardson Formula 20 (KR-20), yielding a coefficient of 0.810, which indicates acceptable reliability for educational assessments (Taber, 2018).

The same instrument was administered as both a pretest and a posttest to allow for direct measurement of changes in students' performance over time. While the use of identical test forms may introduce potential testing effects, precautionary measures were implemented to minimize this limitation. These included maintaining an appropriate interval between test administrations, withholding feedback on correct answers after the pretest, and varying the order of test items during the posttest.

Data Gathering Procedure

Data collection was conducted through a systematic and structured procedure to ensure consistency, reliability, and replicability of the study. Prior to implementation, approval to conduct the research was secured from the school administration, and coordination was undertaken with the subject teacher regarding the schedule, lesson coverage, and implementation of the intervention.

At the outset of the study, an orientation on Reciprocal Peer Tutoring (RPT) was conducted among the students. The orientation emphasized the value of cooperative learning and clarified the roles of tutor and tutee. Students were guided on the proper use of instructional materials, administration of practice items, verification of responses using the provided solutions, and adherence to step-by-step procedures in assisting peers during the Reciprocal Peer Tutoring sessions, which were conducted within a 14-minute allocation during the discussion of new concepts and practicing new skills (Part 2), with 7 minutes allotted for each role as tutor and tutee. Moreover, the purpose and significance of RPT were clearly communicated.

Following the orientation, a pre-test was administered to both the experimental and control groups under identical testing conditions to assess students' baseline knowledge of Basic Calculus, particularly limits and derivatives. The results of the pre-test were used to establish group comparability and to organize student pairings within the experimental group. A ranked-pairing method was employed, wherein students were paired heterogeneously based on their pre-test performance to promote balanced peer interaction during the RPT sessions.

The instructional phase was conducted over four weeks during regular class hours, with sessions held four times per week, each lasting approximately 60 minutes. Both the experimental and control groups were taught the same Basic Calculus competencies, following the prescribed curriculum to ensure consistent exposure to content. The two groups followed the same lesson sequence, which included: reviewing previous lessons or presenting new content; establishing lesson objectives; presenting examples; discussing new concepts and practicing new skills (Part 1); developing mastery; identifying practical applications; making generalizations; evaluating learning; and conducting enrichment or remediation activities.

However, the groups differed during the phase of discussing new concepts and practicing new skills (Part 2). The experimental group engaged in Reciprocal Peer Tutoring, whereas the control group performed similar activities without structured RPT. In the experimental group, students were paired and alternated roles as tutor and tutee. The tutor facilitated problem-solving, explained concepts, and posed guiding questions, while the tutee solved problems and verbalized understanding. Roles were systematically alternated to ensure equal participation.

To support implementation, structured learning materials, such as activity sheets, guided problem sets, and step-by-step prompts, were provided. Correct answers and solutions were included to help students provide accurate explanations. When the tutee provided a correct response, the pair proceeded to the next item, if time remained. If the response was incorrect, the tutor provided a step-by-step explanation based on the provided materials. The tutor then evaluated the tutee's responses and clarified misconceptions. After completing the tasks, students exchanged roles to maintain balanced participation. At the end of each session, learners were allowed to ask the instructor questions.

During the sessions, the teacher served as a facilitator, monitoring student interactions, providing assistance as needed, and ensuring adherence to the RPT process. A monitoring checklist was utilized to assess student engagement, role performance, and compliance with the structured session format. To ensure fidelity of implementation, the researcher regularly verified that key components of RPT, such as role alternation, use of instructional materials, and active participation, were consistently practiced throughout the intervention.

Upon completion of the four-week intervention, a post-test was administered to both groups under uniform testing conditions. The completed test papers were collected immediately, and students' responses were checked, recorded, and organized for subsequent statistical analysis.

Data Analysis Procedure

The researcher personally retrieved the pretest and posttest results to ensure the data were complete and accurate. The scores were consolidated, coded, and tabulated for statistical analysis, while the confidentiality of participants was strictly maintained throughout the process. Descriptive statistics, including mean and standard deviation, were computed to summarize students' pretest and posttest performance. To examine differences in posttest scores between the experimental and control groups while controlling for initial differences, Analysis of Covariance (ANCOVA) was employed. In this analysis, posttest scores served as the dependent variable, group (experimental and control) as the independent variable, and pretest scores as the covariate. The use of ANCOVA allowed adjustment for baseline differences and provided a more accurate estimate of the intervention's effect. Statistical significance was tested at the 0.05 level.

Ethical Consideration

Ethical standards were rigorously observed throughout the study. Prior to data collection, formal authorization to conduct the research was obtained from the school administration. The research procedures underwent institutional review at the school level to ensure compliance with established ethical guidelines governing educational research involving human participants.

The participants were Grade 11 senior high school students and were therefore considered minors. Accordingly,

appropriate ethical safeguards were implemented. Written informed consent was obtained from parents or legal guardians prior to participation, and student assent was secured after a clear, age-appropriate explanation of the study's objectives, procedures, duration, and participant rights. Participants were informed that the study involved regular instructional activities and posed no foreseeable physical, psychological, or academic risk.

Participation in the study was entirely voluntary. To minimize potential influence arising from teacher–student authority relationships, students were explicitly informed that participation, refusal to participate, or withdrawal from the study would not affect their academic grades, classroom standing, or relationship with their teachers or the institution. Participants were assured of their right to withdraw at any stage of the research without penalty or adverse consequences, and no coercion, incentives, or undue pressure was employed.

Confidentiality and anonymity were maintained throughout the research process. Participant identities were protected using coded identifiers during data collection, analysis, and reporting. All data were utilized solely for research purposes and were securely stored to prevent unauthorized access. These procedures ensured adherence to fundamental ethical principles, including respect for persons, voluntary participation, beneficence, and confidentiality in educational research.

Results and Discussion

Descriptive Statistics of Pretest Scores of the Experimental and Control Groups

The pretest scores for the experimental and control groups are presented in Table 1 to describe participants' baseline performance prior to the intervention. The experimental group obtained a mean score of *(M = 14.95, SD = 4.08),* while the control group recorded a mean score of *(M = 14.15, SD = 4.21).* The small difference between the mean scores indicates that the two groups had comparable levels of prior knowledge in Basic Calculus. The similar standard deviation values further suggest that the distribution of scores in both groups was comparable. However, variations in factors such as classroom environment and prior learning experiences may still exist.

Table 1. *Pre-test of the Experimental Group and Control Group*

Group	N	Mean	Standard Deviation
Experimental	38	14.95	4.08
Control	40	14.15	4.21

Establishing baseline comparability is a key consideration in quasi-experimental research, as it helps reduce the influence of pre-existing group differences while not eliminating potential confounding variables (Fraenkel et al., 2019; Shadish et al., 2022). In the context of peer-assisted learning, similar starting points may facilitate more balanced interaction; however, outcomes may still be shaped by contextual and instructional factors beyond initial ability (Topping, 2005).

Comparison of Posttest Performance Using ANCOVA

An analysis of covariance (ANCOVA) was conducted to examine differences in posttest performance between the experimental and control groups while controlling for pretest scores. As shown in Table 2, pretest scores (covariate) had a statistically significant effect on posttest performance, $F(1, 75) = 100.84$, $p < .001$, partial $\eta^2 = .57$, indicating that prior knowledge significantly influenced students' academic outcomes. After adjusting for pretest scores, a statistically significant difference in posttest performance was found between the groups, $F(1, 75) = 152.92$, $p < .001$, partial $\eta^2 = .67$. This finding indicates that the instructional intervention had a significant effect on students' performance. Specifically, students in the experimental group who received Reciprocal Peer Tutoring (RPT) achieved significantly higher posttest scores than those in the control group who received conventional instruction. The large effect size (partial $\eta^2 = .67$) suggests a strong and meaningful difference between the two groups.

Table 2. *Analysis of Covariance (ANCOVA) of Posttest Scores Between Groups*

Source	Sum of Squares	df	Mean Square	F-value	p-value	Partial η^2
Pretest (Covariate)	800.18	1	800.18	100.84	< .001	.57
Group (RPT vs. Control)	1213.46	1	1213.46	152.92	< .001	.67
Error	595.13	75	7.93			

The findings of the present study support existing evidence that reciprocal peer tutoring can enhance students' academic performance in mathematics regarding rational algebraic expression (Abdulkarim et al., 2022). Such

approaches promote active engagement and facilitate deeper understanding through structured interaction and collaborative problem solving.

However, while the observed improvement can be largely associated with the instructional intervention, it is also important to consider other contributing factors that may have supported students' learning. Variations in student motivation, the quality of classroom interactions, and the use of structured learning materials may have complemented the effectiveness of Reciprocal Peer Tutoring (RPT). Additionally, the use of intact class sections reflects typical classroom conditions, which enhances the ecological validity of the findings, although it may also involve pre-existing group characteristics. Taken together, these considerations suggest that the positive outcomes of RPT are likely strengthened by both the instructional strategy itself and the broader learning context in which it was implemented.

Overall, the results suggest that Reciprocal Peer Tutoring is a promising instructional approach for improving students' learning in Basic Calculus, with a focus on limits and derivatives. Nevertheless, further studies employing more rigorous experimental designs are recommended to strengthen causal inferences and better isolate the intervention's effects.

Conclusion

This study provides empirical evidence that Reciprocal Peer Tutoring (RPT) is an effective instructional approach for improving students' academic performance in Basic Calculus. The results revealed that, after controlling for pretest scores, students exposed to RPT obtained significantly higher posttest scores than those who received conventional instruction, indicating the positive impact of structured peer-assisted learning. The findings suggest that collaborative and student-centered strategies can enhance students' conceptual understanding, engagement, and problem-solving skills in cognitively demanding mathematical topics. By allowing learners to alternate roles as tutor and tutee, RPT promotes active participation and deeper processing of mathematical concepts, which are essential for mastering topics such as limits and derivatives.

These results imply that teachers may integrate peer-assisted learning strategies as complementary approaches to traditional instruction, particularly in subjects that require high levels of reasoning. The use of structured peer interaction may help address learning gaps and improve student participation in mathematics classrooms. However, since the study utilized existing class groups, the results should be interpreted with caution. Future research may further examine the effectiveness of Reciprocal Peer Tutoring across different contexts and over a longer period.

Overall, the study highlights the potential of Reciprocal Peer Tutoring as a practical and effective strategy for enhancing students' learning outcomes in Basic Calculus and supports its integration into classroom instructional practices.

Contributions of Authors

Author 1: conceptualization, proposal writing, development of learning materials, data gathering, data analysis
Author 2: proposal writing, development of learning materials, data gathering
Author 3: proposal writing, development of learning materials, data gathering

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Conflict of Interests

No conflict of interest.

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