World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

CalcEs-supported activities in reciprocal teaching on senior high school students' mathematics learning

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World Journal of Advanced Research and Reviews, 2024, 23(03), 2148–2155

Publication history: Received on 07 August 2024; revised on 17 September 2024; accepted on 19 September 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.23.3.2880

Abstract

CalcEs is an educational software application that enhances students' comfort and efficiency in problem-solving. The integration of reciprocal teaching with educational software like CalcEs not only improves mathematical understanding but also aligns with the broader goals of developing 21st-century skills, such as critical thinking, collaboration, and digital literacy. This quasi-experimental research investigated the impact of CalcEs-supported activities on students' performance in General Mathematics. The control group, consisting of 24 Grade 11 Humanities and Social Sciences (HUMSS) students, used conventional teaching methods, while the experimental group, comprising 30 Grade 11 Shielded Metal Arc Welding (SMAW) students, engaged in reciprocal teaching with CalcEs supported activities. Significant differences were observed in the pre-test and post-test scores within both groups, as well as between the post-test scores of the two groups, indicating that CalcEs-supported activities in reciprocal teaching positively influenced student performance.

Keywords: Calces-Supported Activities; Conventional Teaching; Reciprocal Teaching; Mathematics Achievement

1. Introduction

Some educators employ common problem-solving strategies such as computing, simplifying, using equations, or creating models to make learning more interactive and effective. A prevalent approach in mathematics is structured problem-solving, which typically involves steps like reading the problem, devising a plan, solving the problem, and checking the work. Given that mathematics requires systematic procedures and logical steps to solve problems, mastering these skills necessitates consistent practice and deep understanding.

The 2022 Programme for International Student Assessment (PISA) reported that students in the country struggled with modeling complex situations mathematically and faced challenges in selecting, comparing, and evaluating appropriate problem-solving strategies. These findings highlight a critical need to develop strategies that enhance students' critical thinking and problem-solving abilities. Positive educational interventions have shown to be effective in improving academic achievement in mathematics, particularly in problem-solving contexts [1]. In addition to conventional methods, reciprocal teaching strategies offer a collaborative approach that further encourages critical thinking among students.

One of the primary goals of teaching mathematics is to empower students to confidently use mathematical principles to analyze and solve real-life problems [2]. The authors emphasize the importance of integrating students' mathematical performance into the curriculum and instructional practices. These practices can range from basic manual calculations to the utilization of advanced computational software, making the learning process more relevant and accessible.

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Among the various tools available, CalcEs, which is a Calculus software calculator, stands out as a powerful educational software application that enhances students' comfort and efficiency in problem-solving. By incorporating CalcEs-supported activities into the curriculum, educators can provide a scaffolded, child-centered learning experience that accelerates the development of problem-solving skills. When integrated with a reciprocal teaching strategy—where students take turns acting as the teacher—CalcEs can significantly enhance collaborative learning and critical thinking.

To address the issue on problem solving, CalcEs-supported activities were introduced to improve students' problem-solving capabilities. General Mathematics topics in senior high school are quite challenging, which include functions, rational functions, inverse functions, exponential functions, logarithmic functions, simple and compound interest, annuities, stocks, bonds, and logic, provide a comprehensive foundation for students. However, the specific challenges in mastering logarithmic functions led the researchers to conceive this study within the context of reciprocal teaching supported by CalcEs activities.

The integration of reciprocal teaching with educational software like CalcEs not only improves mathematical understanding but also aligns with the broader goals of developing 21st-century skills, such as critical thinking, collaboration, and digital literacy. Reciprocal teaching includes students taking on the role of the teacher in small groups, where they practice and apply definite solving strategies. Research supports the idea that when students are actively engaged in their learning, particularly through technology-enhanced methods, their motivation and achievement levels increase [3]. Furthermore, the adaptive nature of educational software allows for personalized learning experiences that meet the diverse needs of students, thereby maximizing the effectiveness of reciprocal teaching strategies[4].

The use of CalcEs in conjunction with reciprocal teaching represents a promising approach to improving students' mathematical abilities, particularly in challenging areas such as logarithmic functions. This study aimed to explore the effectiveness of this integrated method in enhancing students' performance in General Mathematics, contributing to the broader discourse on innovative teaching practices in mathematics education. The use of CalcEs-supported activities could provide a significant impact on the performance of students in one of the senior high schools in North Cotabato, Philippines, in General Mathematics particularly in logarithmic function, equations, and inequality.

Specifically, this study sought answers to the following questions:

- What are the pre-test and post-test scores of the control group?
- What are the pre-test and post-test scores of the experimental group?
- Is there a significant difference between the pre-test and post-test scores of the control group?
- Is there a significant difference between the pre-test and post-test scores of the experimental group?
- Is there a significant difference between the post-test scores of the control group and the experimental group?

The study has the following hypotheses which were tested using statistical analysis.

- H_{0_1}: There is no significant difference between the pre-test and post-test scores of the control group.
- H_{0_2}: There is no significant difference between the pre-test and post-test scores of the experimental group.
- H_{0_3}: There is no significant difference between the post-test scores of the control group and the experimental group.

2. Methodology

2.1. Research Design

A quasi-experimental research design was employed in this study, wherein the performances of a control group and an experimental group were compared. Although quasi-experimental design does not provide the same level of control as true experiments, they can still provide reliable insights when interpreted with caution due to the potential effect of confounding variables. In this study, the control group received instruction through conventional teaching methods, while the experimental group participated in CalcEs-supported activities integrated with a reciprocal teaching strategy, specifically in learning General Mathematics.

To evaluate the effectiveness of these instructional approaches, the researchers conducted a pretest and posttest on both groups. The pretest was administered to establish a baseline of the students' knowledge and skills in solving logarithmic equations. Following this, the control group was taught using traditional, lecture-based methods, where the teacher explained the concepts and solved logarithmic equations using standard procedures. This approach, although widely practiced, often involves a one-way transfer of knowledge from teacher to student, with limited student interaction and engagement.

In contrast, the experimental group was introduced to the same logarithmic concepts but through a more dynamic and student-centered approach. The researchers employed a reciprocal teaching strategy supported by CalcEs, a computational software designed to enhance problem-solving in mathematics. In this setting, students took on the roles of both learner and teacher, engaging in activities that required them to explain concepts, ask questions, and solve problems collaboratively using the software. CalcEs provided interactive tools that allowed students to visualize and manipulate logarithmic functions, offering immediate feedback that reinforced their understanding and encouraged deeper exploration of the topic.

Posttest results were then analyzed to measure the impact of these differing instructional methods on student learning outcomes. The comparison between the pretest and posttest scores within each group, as well as between the two groups, offered insights into the effectiveness of reciprocal teaching combined with technology versus traditional teaching methods.

The findings of this study are expected to contribute to the growing body of research that supports the integration of technology and innovative teaching strategies in mathematics education. Previous studies have shown that reciprocal teaching can significantly enhance students' critical thinking and problem-solving skills [5], [6]. Additionally, the use of educational software like CalcEs has been found to improve students' engagement and understanding of complex mathematical concepts [3].

By combining these approaches, the study aims to demonstrate that students not only gain a better conceptual understanding of logarithmic equations but also develop the confidence and skills necessary to apply these concepts in various contexts. The integration of CalcEs in the reciprocal teaching strategy also aligns with current educational trends that emphasize the importance of digital literacy and collaborative learning in preparing students for the demands of the 21st century [4], [7].

2.2. Research Locale

This study was conducted in one of senior high schools in North Cotabato, Philippines. The school was formally established in 1968. The school has a total of 651 students with 482 junior high school students and 169 senior high school students for the school year 2023-2024.

2.3. Respondents of the Study

The researchers employed a complete enumeration approach, involving all Grade 11 students of the school. Specifically, the study involved 24 Grade 11 Humanities and Social Sciences (HUMSS) students during the school year 2023-2024, who were randomly assigned to a control group irrespective of their gender and prior mathematics grades. For the control group, the researchers utilized a team teaching approach where the topics of logarithmic functions, equations, and inequalities were taught using a reciprocal teaching strategy without the aid of the CalcEs application.

In contrast, the experimental group consisted of 30 Grade 11 students specializing in Shielded Metal Arc Welding (SMAW), similarly selected without regard to gender or previous mathematics performance. This group was exposed to a reciprocal teaching strategy enhanced with the use of the CalcEs application.

2.4. Data Gathering Procedure

A pilot test was conducted to determine that the mathematics performance of the two groups was the same to proceed with this study. After identifying the two groups, the students under the experimental group were instructed to install the CalcEs application and use it during their activity sessions. After each activity, the students presented their individual outputs, supported by the computational tools provided by CalcEs. The researchers developed a comprehensive guide for utilizing CalcEs in relation with the reciprocal teaching method, which was included in the module which took a month (4 week) for the intervention designed specifically for this study.

The integration of educational software such as CalcEs in the reciprocal teaching framework aligns with contemporary trends in mathematics education, where technology is increasingly leveraged to support and enhance student learning. CalcEs, as an interactive computational tool, enables students to visualize mathematical concepts and engage in exploratory learning, which is crucial for understanding abstract topics such as logarithmic functions and inequalities

[3]. Research has indicated that the use of such software not only improves students' engagement but also fosters a deeper understanding of mathematical concepts [7].

Before the conduct of the intervention, the researchers administered the pretest which included the general mathematics lessons. Each respondent in both the control and experimental groups received a research-made questionnaire designed to gather data on various aspects related to the study. These questionnaires sought to capture the students' performance outcomes, providing a comprehensive overview of the effectiveness of the instructional strategies employed.

2.5. Research Instrument

The researcher utilized a survey questionnaire. A researcher-made test was administered to the identified respondents. This consists of a 30-item test from the different learning competencies of logarithmic function in General Mathematics indicated in the Most Essentials Learning Competencies (MELCs) of Grade 11 General Mathematics. Further, one of the researchers was formerly a division-level writer of modules during the Modular Delivery System as Mathematics Unified Learning Activity Sheets (MULAS) Writing of the Division of Cotabato. Topics Included in the Learning Competencies of Grade 11 General Mathematics were based on the required competencies.

After gathering the test questionnaire, the data were collated, tallied, and tabulated for the purpose of presenting the results of the survey clearly and understandably. Frequency distribution, mean, and t-test for the independent sample were used to determine the significant difference between the pre-test and post-test scores of both the control and experimental groups.

To determine the effectiveness of using the CalcEs-supported activities, the researcher determined the significant difference between the pretest and posttest scores of the control group and experimental group. The following range of scores was used to categorize the students' performance:

Range of Scores	Description	Remarks
25-30	Mastered (M)	Passed
19-24	Closely Approximating Mastery (CAM)	Passed
13-18	Moving Towards Mastery (MTM)	Passed
7-12	Average (A)	Failed
1-6	Low (L)	Failed
0	Very Low (VL)	Failed

This criterion is based on the DepEd K to 12 Grading System and achievement level description equivalent in solving Mean Percentage Score (MPS), DM 076, s.2018 (April 19, 2018) stating the change in the passing score of the 2016 accreditation and equivalency test from 75% to 60%. Sixty percent (60%) of 30 is 18. Therefore, 18 is the passing score. The use of SPSS to determine the t-test (t-test for dependent sample test and t-test for independent samples). The researcher used the mean and standard deviation for descriptive data.

3. Results and discussion

The results aim to determine if the use of CalcEs-supported activities in reciprocal teaching has a significant effect on the performance of students in General Mathematics particularly in logarithmic functions, equations, and inequalities.

Based on Table 1, the control group's pre-test mean score was 9.29, with a standard deviation of 1.88. From the Department of Education K to 12 grading system and the achievement level description for calculating the mean percentage score (MPS), this pre-test score is classified as "average" (A) with a remark of "failed." This classification suggests that students initially struggled with the material, reflecting a need for instructional improvement. Following the intervention, the post-test mean score for the control group increased to 21.46, with a standard deviation of 3.31. This score is interpreted as "closely approximating mastery" (CAM) with a remark of "passed," indicating a significant improvement in students' understanding and performance.

The observed improvement aligns with the findings of Dugard & Todman [8], who noted that pre-test-post-test control group designs are particularly effective in assessing the impact of educational innovations. Such designs are frequently employed in educational research due to their ability to measure learning gains and the effectiveness of instructional strategies. Furthermore, the use of standardized achievement levels, as outlined by DepEd, allows for a more consistent and objective interpretation of student performance, facilitating comparisons across different contexts [9].

Table 1 The Pre-test and Post-test Scores of Grade 11 HUMSS in the Control Group (n=24)

		Pre-test		**Post-test**	
Scores	Description	f	%	f	%
25-30	Mastered (M)	0	0	5	9.80
19-24	Closely Approximating Mastery (CAM)	0	0	16	29.80
13-18	Moving Towards Mastery (MTM)	1	1.90	3	5.70
7-12	Average (A)	20	37.30	0	0
1-6	Low (L)	3	5.60	0	0
0	Very Low (VL)	0			0
	Mean:	9.29 (A)		21.46 (CAM)	
	SD:	1.88		3.31	

This data supports the effectiveness of the instructional methods used, reinforcing the idea that well-structured educational interventions can lead to significant improvements in student outcomes. The shift from "average" to "closely approximating mastery" highlights the potential for targeted teaching strategies to enhance student learning, even in challenging subject areas like mathematics [10].

Table 2 The Pre-test and Post-test Scores of Grade 11 SMAW in the Experimental Group (n=30)

		Pre-test		**Post-test**	
Scores	Description	f	%	f	%
25-30	Mastered (M)	0	0.00	20	37.10
19-24	Closely Approximating Mastery (CAM)	0	0.00	10	18.60
13-18	Moving Towards Mastery (MTM)	4	7.50	0	0.00
7-12	Average (A)	24	44.5	0	0.00
1-6	Low (L)	2	3.80	0	0.00
0	Very Low (VL)	0	0.00		0.00
	Mean:	9.63 (A)		26.53(M)	
	SD:	2.75		3.08	

Table 2 presents the pre-test and post-test scores for the experimental group. Analysis of the data reveals that the mean score of the pre-test is 9.63, with a standard deviation of 2.75. According to the DepEd K to 12 grading system and achievement level descriptions, this pre-test score falls into the "average" (A) range and is categorized as "failed" in terms of achievement level. In contrast, the post-test mean score significantly improved to 26.53, with a standard deviation of 3.08. This post-test result is interpreted as "Mastered" (M) and is remarked as "passed," indicating a substantial enhancement in performance.

Widiartana [11] discussed similar findings in research involving experimental groups where an open-ended instructional approach was utilized. This approach, which fosters active engagement and deeper understanding, aligns with the observed improvement in the experimental group's performance.

Table 3 Significant Difference Between the Pre-test and Post-test Scores in the Control Group

Paired Variable	Mean	Mean Difference	p-value	Decision	Interpretation
Pre-test Scores	9.29				
		12.17	0.000*	Reject H_{01}	Significant
Post-test Scores	21.46				

*significant at 0.05 level

Table 3 shows the difference between the pre-test and post-test scores of the control group. It is indicated that the p-value is less than *0.05 ($p<0.05$)* Thus, the null hypothesis (H_{01}) stating that "*There is no significant difference between the pretest and posttest scores of the control group"* is rejected. This means that there is a significant difference between the pretest and posttest scores of HUMSS 11.

Ozsoy & Yildiz [12] explained the pre-test-post-test design with a control group was applied. Traditional teaching methods have been applied to the control group. Schwerdt & Wuppermann [13] explained that the results of their study indicate that traditional lecture-style teaching is associated with significantly higher student achievement.

Table 4 Significant Difference Between the Pre-test and Post-test Scores of Grade 11 SMAW in Experimental Group

Paired Variable	Mean	Mean Difference	p-value	Decision	Interpretation
Pre-test Scores	9.63				
		16.90	0.000*	Reject H_{02}	Significant
Post-test Scores	26.53				

*significant at 0.05 level

Table 4 shows that the differences that pre-test and post-test scores of the experimental group have significant differences, as it is indicated in the p-value which is less than *0.05 ($p < 0.05$).* Thus, the null hypothesis (H_{02}) stating that "*There is no significant difference between the pretest and posttest scores of the experimental group"* is rejected. This means that there is a significant difference between the pretest and posttest scores of SMAW 11.

Zhang et al. [14] stated that pre-and post-test showed the use of math apps improved students' performance. It implies that the pretest scores of the SMAW 11 have to do with the posttest scores of SMAW 11. Moreover, using reciprocal teaching with CalcEs-supported activities has a significant effect on the performance of SMAW 11 students in General Mathematics particularly in logarithmic functions, equations, and inequalities.

Table 5 Significant Difference Between the Post-test Scores in the Control Group and Grade 11 SMAW in the Experimental Group

Post-test	Mean	Mean Difference	p-value	Decision	Interpretation
Control	21.46				
		5.07	0.000*	Reject H_{03}	Significant
Experimental	26.53				

*significant at 0.05 level

Table 5 shows the significant difference between the post-test scores of Grade 11 HUMSS in the control group and grade 11 SMAW in the experimental group. The mean of the posttest of the control group is 21.46, while the mean of the posttest of the experimental group is 26.53

The result reveals that posttest scores of the control group and experimental group have significant differences as indicated in the p-value of *0.000* which is less than *0.05* ($p < 0.05$). Thus, the hypothesis stating that there is no significant difference between the post-test results of the control and experimental groups(H_{03}) is rejected.

Glaser-Opitz & Budajova [16] introduced a software application (MATH) supporting an educational resource of Applied Mathematics, with a focus on Numerical Mathematics. They emphasized that the tool is an easy-to-use, and convenient tool supporting various numerical methods calculations with a graphical user interface and integrated plotting tool for graphical representation. CalcEs-supported activities in reciprocal teaching helped in this study.

4. Conclusion

The integration of CalcEs-supported activities in reciprocal teaching has implied a positive impact on the performance of students in General Mathematics, particularly in logarithmic functions, equations, and inequalities. This experimental study underscores the potential advantages of combining reciprocal teaching with educational software in mathematics instruction as manifested in the result that there is no significant difference between the post-test results of the control and experimental groups

As educators strive to enhance student outcomes in complex subjects like General Mathematics, innovative methods that blend traditional approaches with technology-enhanced, student-centered strategies hold considerable positive outcome. The use of tools like the CalcEs application, combined with reciprocal teaching strategies, can effectively engage students, particularly those who may be anxious about mathematics. By tailoring educational tools and strategies to accommodate diverse learning styles and needs, educators can foster a more inclusive and effective learning environment.

Compliance with ethical standards

Acknowledgements

The authors would like to thank everyone who took part and contributed to the success of this study particularly the principal, teachers and students of the senior high school who religiously participated in this research endeavor.

Disclosure of Conflict of interest

The authors declare that there is no conflict of interest in this study.

Statement of ethical approval

This study followed an ethical approval.

Statement of informed consent

Informed consent was obtained from all individual participants included in this study.

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