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Students' Learning Outcomes on Circle Equations Through Desmos Graphing Calculator

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Abstract

Graphical representations of mathematical equations, particularly circle equations, play a crucial role in conceptual learning. This study investigated the effect of the Desmos Graphing Calculator (DGC) application on students' test scores in circle equations, assessed the significance of the differences in scores before and after using the application, and explored students' experiences with the tool. Utilizing a one-group pretest-posttest design, the research employed both quantitative and qualitative methods. The test instrument demonstrated a reliability value of 0.85, involving 50 student participants from the Integrated Laboratory Science High School at Mindanao State University-Maguindanao. Data analysis was performed using the Wilcoxon Signed Ranks Test. The results revealed 0 Negative Ranks, 50 Positive Ranks, and 0 Ties, indicating that no students scored higher before the intervention, while all students achieved higher scores afterward, with no ties in scores. The pretest mean score was 8.18, which increased to a posttest mean score of 28.52, yielding a Z value of -6.157 and a p-value of .000. This indicates a significant improvement in students' test scores following the use of the application. Additionally, qualitative feedback from students highlighted the effectiveness of the DGC in enhancing their understanding of circle equations. Overall, the findings suggest that the DGC is an effective tool for enhancing student performance in understanding circle equations.

Keywords: Circle Equations, Desmos Graphing Calculator, Graphical Representation, Innovative Graphing Tool, Learning Outcomes.

Introduction

Graphical representations of mathematical equations, particularly those involving circles, are crucial for conceptual learning and comprehension. The ability to recognize and express the same concept through various methods or representations enables students to perceive relationships more clearly, thereby enhancing their understanding (1). Currently, most instructional content is delivered using markers and whiteboards, with classroom learning often limited to presentations via PowerPoint. However, the static nature of whiteboard representations restricts the exploration of how coefficients in mathematical equations—especially in calculus topics like circle equations—affect the graph. Consequently, students may struggle to understand the impact of changing coefficients on the equation's graph, which can lead to decreased motivation. To foster students' interest in learning and improve the quality of education, teachers must continuously innovate by employing diverse learning models and appropriate teaching aids. One significant innovation in education is the integration of technology into the learning process (2). The use of technology in the classroom is intended to engage students and address learning challenges, particularly in subjects like mathematics that require visualization and graphical representation (3). Technology serves as a valuable tool for assessing learning and enhancing student motivation, interest, and understanding, while also presenting data in a compelling and accessible manner, simplifying complex information. In light of these challenges and recognizing the critical role of technology in education, this study aims to evaluate students' learning outcomes in circle equations through the use of innovative graphing tools, specifically the Desmos Graphing Calculator (DGC) application.

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The DGC is known for its user-friendly interface and effectiveness in visualizing mathematical concepts, which likely contributed to its selection as a tool for enhancing students' understanding of circle equations.

Students' Common Experiences on Graphical Representation

A common finding in many studies is that students often struggle to grasp the models and language necessary for illustrating, manipulating, and representing mathematical concepts (4). Research in mathematics education indicates that students typically exhibit weak representation and visualization skills in calculus, particularly concerning circle equations. This deficiency frequently leads to a lack of meaningful understanding of the formal aspects of mathematical analysis. Some researchers attribute students' errors to inadequate handling of representations or a lack of coordination among different types of representations (5). Generally, students tend to overlook verbal and intuitive representations. Furthermore, many teaching methods do not effectively facilitate the transition from one type of representation to another, a challenging process that is essential for the generalization of mathematical concepts (6).

Desmos Graphing Calculator (DGC)

The DGC is a free, open online tool that provides extensive numerical and visual capabilities. It allows users to plot points on the Cartesian plane, solve equations and inequalities, graph functions, and generate regression models from data sets. The advantages of using DGC in educational settings are: it is a free resource that requires no subscription or registration; users can create both dynamic and static graphical displays, as well as conduct quantitative analysis of two-dimensional models; the platform offers a variety of pre-built activities and demonstrations to enhance learning; only basic technology skills are needed to effectively utilize the platform; and it facilitates easy sharing of demonstrations with other users. To use the DGC, users need a laptop or mobile device to access the application. DGC is an extension for Google Chrome that allows users to work with and explore math equations. Users can be able to build tables, graphs, and charts simply by drawing with a mouse or the touchscreen. All the features of a dedicated physical graphing calculator come bundled with Desmos, which makes it suitable for students as well as those who need to perform complex calculations for work. It is also able to make simple animations and draw images, which makes it more attractive to those who must use it for presentations (7).

Innovative Graphing Tool for Graphical Representation

The integration of technology in teaching is anticipated to address student learning challenges and engage students in mathematical content that necessitates visual representation, such as through the use of Desmos software. DGC is a completely free online graphing calculator accessible via both web browsers and mobile devices. Research supporting the advantages of graphical calculators highlights DGC's effectiveness. One study reported that teachers responded positively to using DGC, emphasizing its ease of use, the speed and accuracy with which it produces graphs, and its role in enhancing students' mathematical understanding (8). Similarly, another study investigated the application of DGC in mathematics education and observed improvements in high school students' understanding and learning of functions (9). Further exploration into the benefits of DGC has noted that digital technology can uniquely engage students in mathematics. It facilitates the conducting, observing, and analyzing of mathematical experiments, with features such as high-resolution zoom that clarify mathematical processes. A significant advantage is its emphasis on accessibility, providing visualizations that cater to students with various disabilities, thereby surpassing the capabilities of traditional print forms and mechanical devices (10).

Methodology

The study employed a one-group pretest-posttest research design. The test instrument utilized in this research demonstrated a reliability value of 0.85, indicating that it is a good test. The researchers implemented a five-day intervention with one-hour sessions each day since the content coverage, cognitive load, student interaction, and availability of the resources were considered. The participant group consisted of 50 students, comprising 33 females and 17 males. These participants were Mathematics 10 students from the Integrated Laboratory Science High School at Mindanao State University – Maguindanao. The researchers began by administering a pretest to assess students' baseline knowledge of circle equations. Following this assessment, circle equations were introduced to the students using a direct instruction strategy. Subsequently, the innovative DGC application was introduced, specifically utilizing its "Conic Sections: Circle" feature to visualize circle equations effectively. Students engaged in hands-on exploration with the DGC through a series of interactive activities. They worked both individually and in collaborative groups, fostering a supportive learning environment. Guided practice exercises were provided to help students navigate the tool and deepen their understanding. This approach allowed students to manipulate various parameters and observe the resulting changes in the circle graphs, enhancing their conceptual grasp of the material. After the intervention, the researcher administered a posttest to evaluate students' learning outcomes. The posttest covered the same concepts as the pretest to measure knowledge growth. The pretest and posttest scores were analyzed using the Wilcoxon Signed Ranks Test, as the distribution was not normal. This analysis aimed to determine whether there were significant improvements in students' understanding of circle equations following the intervention. Lastly, provided feedback to students and encouraged reflection on their learning experiences with circle equations using the graphing tool. The following Figure 1 illustrates the one-group pretest-posttest research design used in the study. This design was used to evaluate the effect of a treatment by comparing measurements taken before and after the intervention. The pretest and the posttest are made in different days (11).

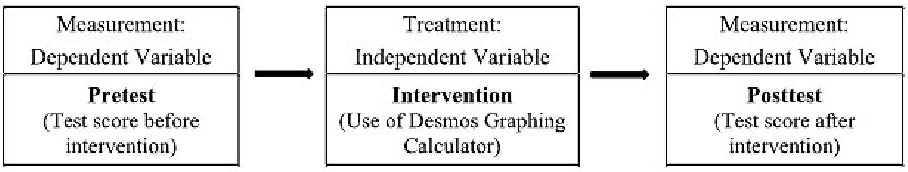

Figure 1: The One-Group Pretest-Posttest Research Design

Results and Discussion

The Effect of the Desmos Graphing Calculator Application on Students' Test Scores in Circle Equations

Figure 2 below illustrates the distribution of pretest and posttest scores, highlighting the changes in student performance before and after the intervention. The data indicate an increase in scores from the pretest to the posttest, with the posttest scores demonstrating greater variability.

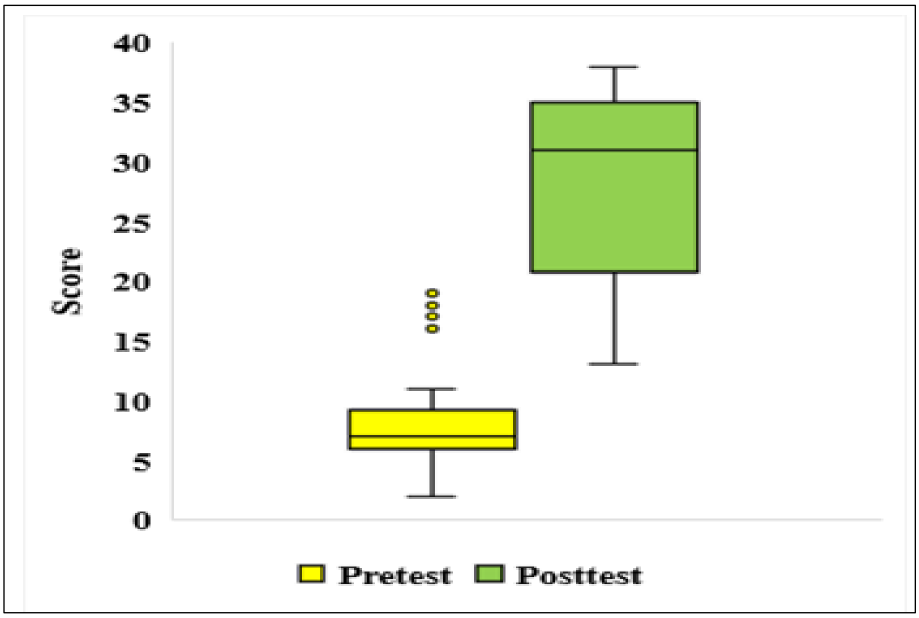

Figure 2: Distribution of Pretest and Posttest Scores of Students

Table 1: Frequency Distribution of Mean Gain of Students' Test Scores in Circle Equations

Type	F	%
With Gain	50	100
No Gain	0	0
Decrease	0	0
Total	50	100%

Table 1 illustrates the mean gain of students' test scores in circle equations. The results indicate that there were no students categorized under "No Gain" or "Decrease," while all 50 students demonstrated improvement, classified as "With Gain." This finding suggests that every student enhanced their performance after utilizing the DGC application. Furthermore, a meta-analysis of research studies on the use of calculators revealed that students who employed calculators achieved significantly higher scores and exhibited more positive attitudes toward mathematics compared to those who did not use calculators (12). In addition, another research highlighted that graphic calculators help students better understand the concept of graphing functions and improve their skills in interpreting and constructing graphs. The study noted that students who used graphing calculators showed a greater improvement in their understanding of mathematical concepts compared to those who did not use such tools (13).

The Significant Difference in Students' Test Scores

The pretest and posttest scores were compared to determine if there was a significant difference in students' performances before and after the intervention. The results of the tests for normality are presented in Table 2, while Figures 3 and 4 below illustrate the distribution normality of the scores. Given the non-normal distribution, the Wilcoxon Signed Ranks Test was employed to analyze the data, with descriptive statistics, ranks, and test statistics detailed in Tables 3, 4, and 5.

Table 2: Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
Pretest	.173	50	.001	.867	50	.000
Posttest	.156	50	.004	.894	50	.000

a. Lilliefors Significance Correction

Table 2 displays the results of both the Kolmogorov-Smirnov and Shapiro-Wilk tests, which assess the normality of the pretest and posttest score distributions. The p-values for both tests were less than 0.05, indicating that the distributions were not normal. Consequently, the Wilcoxon Signed Ranks Test was deemed appropriate for comparing the scores and determining if a significant difference existed between the pretest and posttest results. Figures 3 and 4 below provide a visual representation of the pretest scores and posttest scores distributions, further supporting the decision to utilize the Wilcoxon Signed Ranks Test for analyzing the differences in scores.

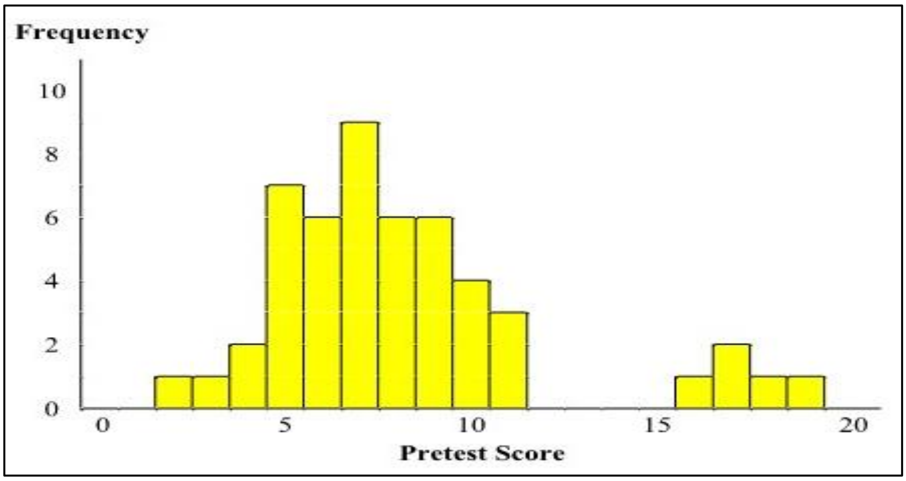

Figure 3: Distribution of Pretest Scores

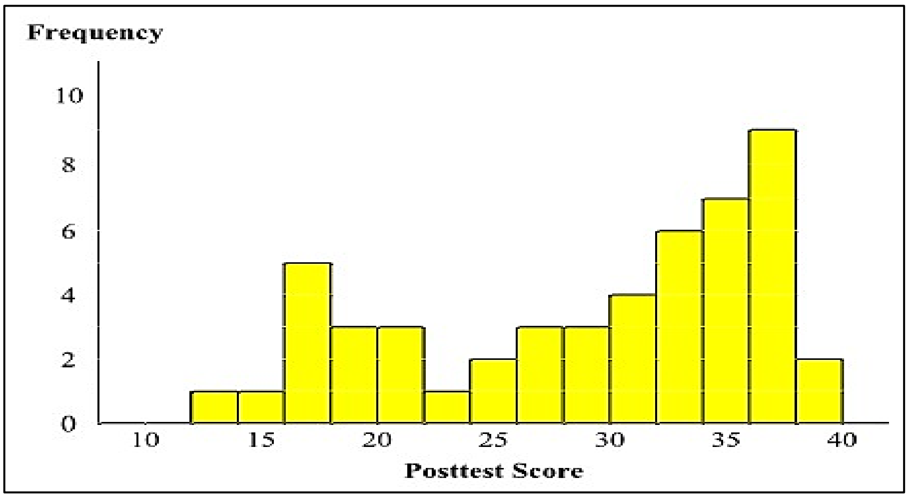

Figure 4: Distribution of Posttest Scores

Table 3: Descriptive Statistics of Pretest and Posttest Scores of Students

	N	Mean	Std. Deviation	Minimum	Maximum	Percentiles 25th	Percentiles 50th (Median)	Percentiles 75th
Pretest	50	8.18	3.735	2	19	6.00	7.00	9.25
Posttest	50	28.52	7.643	13	38	20.75	31.00	35.00

Table 3 presents the descriptive statistics for the 40-item pretest and posttest scores of students, including the Number of Observations (N), Mean, Standard Deviation (SD), Minimum, Maximum, and Percentiles for test scores before and after the intervention. The results indicate that the average test score before the intervention was 8.18 (M = 8.18; SD = 3.735), with a minimum score of 2, a maximum score of 19, and a median score of 7.00. In contrast, the average test score following the intervention increased to 28.52 (M = 28.52; SD = 7.643), with a minimum score of 13, a maximum score of 38, and a median score of 31.00. This data implies that there is an improvement in scores from the pretest to the posttest. Similarly, a study demonstrated the existence of a significant difference in the mean scores between two groups; students who used graphing calculators performed better in problem-solving tasks compared to students without access to graphing calculators. The integration of technology in education positively impacts student achievement (14).

Table 4: Ranks of Pretest and Posttest Scores of Students

		N	Mean Rank	Sum of Ranks
Posttest – Pretest	Negative Ranks	0[a]	.00	.00
	Positive Ranks	50[b]	25.50	1275.00
	Ties	0[c]		
	Total	50		

a. Posttest < Pretest; b. Posttest > Pretest; c. Posttest = Pretest

Table 4 illustrates the ranks of pretest and posttest scores for students, detailing the Number of Students (N) in Negative Ranks, Positive Ranks, and Ties, along with their Mean Rank and Sum of Ranks. The results indicate that there were no students in Negative Ranks (0[a]), while all 50 students were categorized in Positive Ranks (50[b]), yielding a Mean Rank of 25.50 and a Sum of Ranks of 1275.00. Furthermore, there were no students in Ties (0[c]). This outcome implies that no students achieved a higher test score before the intervention, while all students improved their scores after the intervention. Additionally, no students maintained the same test scores before and after the intervention. Supporting this finding, a study reported that educational practices enriched with educational technology lead to improved performance, indicating that students with access to educational technology, including graphing calculators, demonstrated enhanced performance in mathematics (15). The study noted significant increases in test scores, aligning with the improvements observed in the current study. It was also confirmed that students participating in the intervention showed notable gains in their mathematical understanding and test scores from pretest to posttest, suggesting that educational technology applications have a positive impact on mathematics achievement (16).

Table 5: Test Statistics[a] of Pretest and Posttest

	Posttest – Pretest
Z	-6.157[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test; b. Based on negative ranks

Table 5 presents the test statistics for the pretest and posttest scores, which are essential for determining whether to reject the null hypothesis. The results revealed a Z value of -6.157[b] and an Asymp. Sig. (2-tailed) p-value of .000. Since this p-value is less than 0.05, we reject the null hypothesis. This implies that there is a significant difference in test scores before and after the intervention.

The Students' Experiences Using the Desmos Graphing Calculator

Some of the students' reflections on their experiences using the DGC to understand circle equations are summarized in Table 6 while Figure 5 provides a visual representation of classroom activities involving the use of the DGC.

Table 6: The Students' Experiences Using the Desmos Graphing Calculator

Theme	Student's Comments
Ease of Use and Interface	"I find the user interface of the Desmos Graphing Calculator very helpful and useful in terms of visualizing circle concepts. I was amazed by its appearance." "Certainly! I can say that it is a very useful application, especially to students that take time to graph equations." "I like the part where you can just enter the equation and you'll be able to see the graph." "It is easy to use, and it consumes a short time when graphing. It can be used offline and no ads will disturb you when using the application." "It has a small MB when downloading and it can be used

	offline or without an internet connection. The application can visualize and manipulate the equation easily.”
Enhanced Understanding and Visualization	“The Desmos enhanced my understanding of circle concepts easier and more accessible. This application is real-time friendly. It made me visualize the equation faster.”
	“The Desmos application helps us a lot to visualize the location of the circle in the plane in a faster way than the traditional method.”
	“By just putting your equation on the assigned feature, the circle will immediately be plotted in the graph.”
	“The Desmos enhanced my understanding of circle equations. Now, I can easily identify the center and the radius of a circle.”
Features and Functionality	“The most useful feature is the equation section where we only have to type the center in the provided standard form equation.”
	“It is a good application. I enjoyed using this in supporting my mathematical learning journey. I had a chance to explore graphing different equations.”
Suggestions for Improvement	“Hoping for the improvement on the graph where the ordered pair (x, y) will be stated already beside the points.”
	“The graph of a circle looks like an oval shape when zooming the graph using a phone. It is confusing when the x and y axes of the graph are expanding.”
	“The only thing that bothered us was the absence of its manual to guide us a beginner. It would be better if there is a problem solver that shows the steps how to solve it.”

Based on the students' experiences in Table 6, it is clear that the DGC has significantly impacted their understanding and visualization of circle equations. The tool's user-friendly interface, real-time graphing capabilities, and offline accessibility have made it a valuable resource for many. Students particularly appreciate the ease with which they can enter equations and instantly see the corresponding graphs, enhancing their learning efficiency and enjoyment. However, some areas for improvement include providing a manual for beginners, better zoom functionality on mobile devices, and additional features like a problem solver and labeled coordinate points. Overall, the DGC proves to be an effective educational tool but addressing these concerns could further enhance its utility and user experience. The following figure showed the students actively engaging in hands-on activities with the DGC, demonstrating its effectiveness as an educational tool in enhancing learning experiences in circle equations.

Figure 5: Students Utilizing Desmos Graphing Calculator in Classroom Activities

Conclusion

Based on the results, there was a notable increase in test scores from the pretest to the posttest. All students demonstrated higher test scores following the intervention, which indicates a significant improvement in their performance after utilizing the DGC. This evidence suggests that the DGC is an effective tool for enhancing student performance. Consequently, it can be concluded that this innovative graphing tool significantly improves students' learning outcomes in understanding circle equations.

Abbreviations

DGC: Desmos Graphing Calculator, M: Mean, N:Number of Observation, SD:Standard Deviation.

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Author Contributions

Rahmia M. Meto (Author 1): Visualization, Conceptualization, Investigation, Methodology, Formal Analysis, Writing - Original Draft, and Writing - review and editing; and Leonard M. Paleta (Author 2): Visualization, Conceptualization, Formal Analysis, Supervision, Validation, and Writing - review and editing.

Conflict of Interest

The authors affirm that this manuscript has not been published previously and is not under consideration by any other journal. The authors declare that the work has not been released as a preprint elsewhere. Furthermore, the authors also disclose that there are no apparent or actual conflicts of interest for any of the authors involved in this study.

Ethics Approval

This study was conducted in accordance with ethical standards. Participants were provided with comprehensive information regarding the purpose of the research, the procedures involved, and their right to withdraw from the study at any time without any repercussions. Confidentiality and anonymity of the participants were strictly maintained throughout the research process, and all data collected were securely stored.

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