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Use of Desmos Graphing Calculator in Teaching Geometry and its Effect on Secondary Schools Learners' Conceptual Understanding, Kiambu County, Kenya

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ABSTRACT

The use of Desmos Graphing Calculator (DGC) software in secondary schools' geometry education has the potential to improve learners' conceptual understanding. One of the mathematics strands where students struggle is geometry. Over time, a variety of tools and initiatives have been employed to aid pupils in understanding geometry concepts. This paper shares findings from the study aimed to establish the effect of Desmos Graphing Calculator on secondary school learners' conceptual understanding of geometry in Kiambu County, Kenya. The research adopted the Technology Acceptance Model of which the quasi- experimental research design was used with pre-post testing procedures. The study participants were 176 students and four teachers. Four schools were sampled and were divided into two control and two experimental groups through a purposive sampling technique. A quantitative method was applied. Data were gathered through questionnaires and achievement tests. Pilot testing was done with two secondary schools in Kiambu County with traits resembling the sample schools which validated the research's instruments andthe Cronbach's Alpha Coefficient of .813 was found for reliability. Using SPSS version 25, the data were analysed. The Independent Sample T-test, Analysis of Variance, and Analysis of Covariance were used to analyse the discrepancies between the groups' means which took into consideration ?=.05 as the level of significance and the results showed that the experimental and control groups' conceptual understanding post-test mean scores differed statistically significantly at ?=38.34. Provide the P score here, this result led to the conclusion that when DGC is used in geometry instruction by mathematics teachers, students' conceptual understanding is enhanced. Finally, since DGC is a significant contribution to the teaching and learning of geometry, the study, therefore, recommends its use and should serve as the foundation for further investigation.

Keywords: Desmos Graphing Calculator, Geometry, Conceptual Understanding, Kenya

INTRODUCTION

The use of mathematical software in the teaching and learning of geometry has the potential to make reasoning less abstract and, overcome students' difficulties in understanding Florio (2022). The rapid expansion of information that is accessible to anyone, everywhere, and the ability to access and share such information wherever the user is physically has changed how individuals organize and conduct their job, interact, and innovate (Hinostroza et al., 2015). These technologies have the potential to improve universal access to education, equality in instruction, teaching and learning quality, teacher professional development, and education system management and administration. As a result, they are critical to the development of more egalitarian communities (Štrajn, 2015).

Desmos Graphing Calculator is an online and mobile application written in Java Script at the first stages of operations for modern graphing. It is used to graph functions, plots, visualize algebraic equations, add slides, animate graphs, etc. There are no limits on how many expressions can be graphed at one time without entering expressions in y=form. Unlike GeoGebra software, Desmos Graphing Calculator Sliders A: helps to develop insight, and interactively change values or quicken any configuration to see its impact on the graph. Among other things, it can deal with absolute value, logs, and square roots. It can handle squareroots, logs, absolute value, display cartesian and polar inequalities, and more. Working with Desmos can be done offline also. Its versatility can have mixed outcomes for the development of mathematics concepts among mathematics learners if not well handled.

According to Kristanto (2021), through the web, iOS, and Android applications, Desmos is a platform or service that provides a range of math tools, digital math exercises, and curriculum to aid students' high-level learning in a fun way. Desmos, he continued, may be used by teachers to enhance the caliber of mathematics instruction, and learning by enabling pupils to engage in real-world mathematical tasks. Meanwhile, Everstova and Sivtseva (2021), exploration opportunities of using a Desmos graphing online calculator in mathematics lessons have an impact on the quality of learning have become current. The advancement of science education requires a solid basis in mathematics. When instructors employed standard textbooks and aided in teaching mathematical ideas of geometry shapes in the past, students were often unable to fully comprehend the principles. Therefore, students must participate actively in their knowledge development when learning geometry. Along with knowing the material, a teacher should also be aware of how students learn and how use them during instruction.

Conceptual comprehension is dependent on the quantity and strength of its connections (Donevska-Todorova, 2022). When coordinate and transformation geometry is taught to students through idea mapping, their conceptual knowledge of the subject may increase (Malatjie & Machaba, 2019). Conceptual understanding is the comprehensive and useful comprehension of mathematical ideas. It enables learners to build on what they have learned and use it to understand new subjects. Instead of utilizing a more conventional method of concentrating on mastering specific subjects, it also entails having pupils participate in high-quality lessons that are based on fundamental principles and ideas. Desmos graphing calculatorwhen used in an engaging, and convincing manner to teach the concept of limit reduces conceptual conflict (Liang, 2016). Therefore, conceptual understanding of learning geometry increases through the usage of graphic representation draw parallels with Geogebra.

Mathematics, especially geometry has seemed over the past decades to be more abstract or require some high levels of imagination. To improve instruction and understanding of geometry by virtualization or semi-abstract, there is so much software including Desmos Graphing Online Calculator that might be utilized. The learners learned mathematics more effectively and efficiently when instructed using computer- generated software.

Students struggle with geometry, one of the strands of mathematics (Alkhateeb & Duwairi, 2019).This paper shares findings on the relationship between using Desmos Graphing Calculator in teaching geometry and secondary school learners' conceptual understanding of geometry concepts, in Kiambu County, Kenya.

Statement of the Problem

Mathematics being key subject in the Kenyan educational system, which requires all students to take it as one of their areas of study. This is because mathematics serves as the basis for many other disciplines, including engineering, architecture, agriculture, medicine, and business. However, Kiambu County has had dismal results in the KCSE Mathematics examinations for a long period despite many efforts such as retraining teachers and providing teaching resources. Those resources have been used over time to help students understand geometry concepts. Geometry is one of the strands in mathematics where the learnersare underperforming. This study used Desmos Graphing Calculator in mathematics classrooms to establish the effect it may have on secondary school learners' conceptual understanding of geometry in Kiambu County, Kenya.

Objective of the Study

The study objective was to establish the effect of Desmos Graphing Calculator on secondary school learners' conceptual understanding of geometry when used.

Theoretical Framework

Considering the theoretical framework of this investigation, the Technology Acceptance Model (TAM) was used. When employed, it radically changed the process of teaching and learning geometry.

According to Davis and Venkatesh (1996), Technology Acceptance Model (TAM) is considered as a theory of computerized systems that depicts how technology adoption and usage occurs among users. Therefore, Technology Acceptance Model provides the ability for both the teachers and learners to accept and use technological tools such as Demos Graphing Calculator. Technology is considered as important to users when it is applied in different fields. In other words, it refers to whether someone believes that technology will be advantageous for their goals. Since the study was based on the technological software application, TAM confidence by teachers and students can result to increase in personal control, adaptability, and professional information utilization. In addition, greater knowledge of the use of technology can boost productivity. Desmos Graphing Calculator is used in the study as a technological software that virtualizes geometry problems. It was accompanied by a computer, projector, electric power supply, internet connectivity, and so on.

In summary, the Technology Acceptance Model connects and attracts learners to the use Desmos Graphing Calculator which is a piece of computer software for education. It also assists in improving learners' conceptual understanding because of its less abstraction and virtualization of geometry lessons. Additionally, it leads to remembrance or retention of the knowledge gained.

REVIEW OF RELATED LITERATURE

In a study conducted by Gargrish et al., (2021) on 1st-year polytechnic students, the experimental outcomes indicated that using geometry learning assistant (GLA) can enhance learners' visualization of the core concepts with memory retention abilities in mathematics. Therefore, Haryani and Hamidah (2022) survey findings, most students can increase their involvement with mathematics study by using paper-based worksheets. These arguments may only be experienced when the teaching approaches considered the attitudes of the learners.

Within a learning environment, the teacher must learn to understand the learner's characteristics, and motivational sources, which are effective feedback design strategies(Maag et al., 2022). Because of recent technological advancements, several digital learning aids for teaching mathematics have been produced. Juman et al. (2022) argued that learners can establish strong mathematical concepts and develop advanced critical thinking when learning geometry with the aid of virtual manipulatives, printed math formulas, and spoken explanations. While Caniglia and Meadows (2018) recommended that Learning how to evaluate resource quality, understanding how to use website resources properly, and addressing the diversity of ways resources can be used to integrate technology into their mathematics curriculum may be beneficial for pre- service teachers. These several technological tools that are available can be utilized successfully when teachers are trained to use them. Additionally, the learning environment must be accessible with the required materials to contribute to educational instruction.

A qualitative study conducted by (Tls& Herman, 2020) in linear programming sessions, Triple E methodology was adopted to assess how well Desmos functions assisted the learners through distance learning with an interesting course extension exercise. However, it was also used to examine the works created by future instructors. It was discovered that by giving pre-service mathematics teachers the chance to consider, design and utilize distance instruction maximize their readiness to develop the technology. Meanwhile, a study carried out in a Portuguese School of Cape Verde to 9th-grade students, indicated that using the Desmos platform was highly favourable with obvious benefits for the students' building of knowledge, centered on a comprehensive growth. They also argued that Desmos platform, which has several engaging math materials helps to enhance geometry instruction and comprehension(Machado et al., 2023). According to Makhdum et al. (2023), to improve students' cognitive development in mathematics lessons, teachers should be able to use appropriate and essential technological assistants at every status. Even though previous research claimed the significant of using ICT tools during instruction, the degree to which the change in behaviour of the learners should be created deeply depends on the teaching process.

Glaze et al., (2021) conducted a study within three Midwestern school districts, USA. There were 93 instructors of mathematics in junior high schools that participated and found that when teachers employ software application for any geometric problem such as online Desmos graphing calculator in teaching mathematics, they help to support students discover new knowledge through visual, computational, and exploratory methods. Additionally, Jaafar et al., (2022) study examined how well technology and applications were used to improve university students' performance, acceptance, interest, and skills inunderstanding and visualizing mathematics learning. They found that these technologies guided academic institutions, instructors, and schools seeking innovative and future-ready instruction. The point to consideras a researcher is that students are motivated and thrilled as they learn mathematics using digital technology.

Therefore, Desmos graphing calculator's effect on learners' conceptual understanding helps to increase their cognitive memory retention in mathematics. The measurement of the cognitive retention of each student is cardinal to the instruction process. Keeping new information in long-term memory is a process known as learning retention. This shows that you have effectively retained the knowledge and can recollect it later. DGC benefits include and are associated with learners' motivation and increase in academic achievement. Additionally, the development of logical skills and analytical thinking, the construction of knowledge, enable the possibility of learners to use new information and abilities and understand theoutcomes that can be attained.

RESEARCH METHODOLOGY

The quantitative method was used in the study. The objective on the effect Desmos Graphing Calculator have on Secondary Schools learners' conceptual understanding when usedwas addressed using the quantitative method. To interpret the data, descriptive and inferential statistics were applied. Additionally, a purposive sampling technique was used to choose four mixed-gender learning institutions in Kiambu County, Kenya, as samples for the quasi-experimental research design because they had relatively better access to electricity, the internet, large laboratory lecture rooms, and other technological tools that supported the research intervention processes. Teachers from experimental groups were trained for one week ontechnical ways of using Desmos Graphing calculator in teaching geometry. This study featured two Experimental groups that were taught about "Gradient, Equation, and Graph of a Straight Line" for three weeks using the Desmos Graphing Calculator software, and the identical lessons were imparted to the two Control groups using the conventional teaching technique. Data were collected using questionnaires and achievement tests through pre-post-testing from both teachers and students. The study participants were 176 students and 4 teachers from Kiambu County, Kenya.

FINDINGS

Proportions of Groups Respondents

The research involved four groups. Two of them were experimental, and the other two were controls. A total of 176 students and four teachers took part in the study. Each group contained 44 students and a teacher.

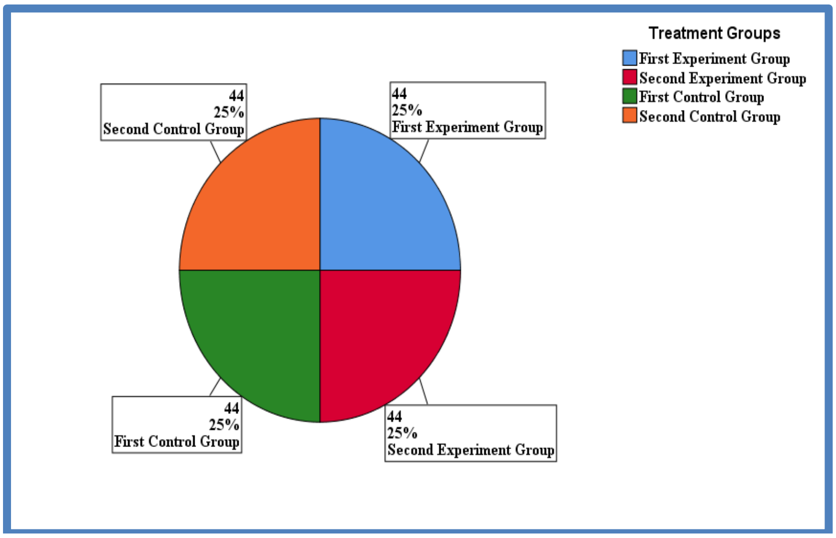

Figure 1: Proportions of Students Groups Respondents

Figure 1, a pie chart displaying the results, shows the frequency and proportion of respondents from each group among the students.

Source: Researcher, 2023.

As depicted in Figure 1, of these respondents, 44 (25%) were assigned to the First Experimental Group, 44 (25%) to the Second Experimental Group, 44 (25%) to the First Control Group, and 44 (25%) to the Second Control group. These percentages indicate that each group had roughly the same number of responders, making it possible to compare groups without bias using statistical tests.

Analysis of the First Experimental Group using Paired Samples T-Test Statistics

The statistics from Table 1's paired sampling t-test were used to analyze the First Experimental Group. This showed a comparison of the same group at different moments of testing. To establish the effect Desmos Graphing Calculator has on secondary school students' conceptual understanding of geometry lessons when it was employed as an intervention, both pre-post achievement tests were given.

Table 1: Paired Samples T-Test and Statistics of the First Experimental Group

		Mean	N	Std. Deviation	Sig. (2-tailed)
Pair 1	Pre-Effect of DGC on Learners' conceptual understanding	7.18	44	3.750	.001
	Post-Effect of DGC on Learners' conceptual understanding	45.89	44	7.160	

Source: Researcher, 2023.

Table 1 shows that the First Experimental Group's pre-post testing sample means (?) were 7.18 and 45.89, respectively. As a result, the mean scores varied by 38. 71. Meanwhile, in the pre-test data set, individual score standard deviation (?) was 3.750 wide apart from each other's, and then in the post-test data set, they were increased to 7.160.

Since the calculated P-value (.001) was less significant than the threshold of significance (?=.05), the null hypothesis is disproven and conclude that there was a statistically noteworthy improvement in students' mental comprehension of geometry as a result of using the Desmos Graphing Calculator within the First Experimental Group geometry lessons.

Analysis of the Second Experimental Group using Paired Samples T-Test Statistics

The statistics from the paired sampling T-test in Table 2 were used to analyze the Second Experimental Group. This demonstrated a comparison of the same group at various testing times. Form Two pupils in Kiambu County who took part in the study provided the information. To ascertain the effect of the Desmos Graphing Calculator on secondary school students' conceptual grasp of geometry classes when it was employed as an intervention, both pre-post achievement tests were given.

Table 2: Paired Samples T-Test and Statistics of the Second Experimental Group

		Mean	N	Std. Deviation	Sig. (2-tailed)
Pair 1	Pre-Effect of DGC on Learners' conceptual understanding	9.70	44	3.801	.001
	Post-Effect of DGC on Learners' conceptual understanding	42.48	44	8.587	

Source: Researcher, 2023.

The pre-post achievement tests recorded sample mean (?) were 9.70 and 42.48 of the Second Experimental Group in Table 2. As a result, the mean scores varied by 32. 78. Also, in the pre-test data set, individual score standard deviation (?) was 3.801 far apart from each other's, and then in the post-test data set, they were reduced to 8.587.

Since the calculated P-value (.001) was less significant than the threshold of significance (?=.05), we get to the conclusion that the presence of the Desmos Graphing Calculator refutes the null hypothesis which led to a statistically significant improvement in learners' conceptual understanding of geometry.

Analysis of the First Control Group using Paired Samples T-Test Statistics

The First Control Group was examined using the statistics from the paired sampling t-test in Table 3. This showed a contrast between the same group at varied testing intervals. The data was provided by Form Two students in Kiambu County who participated in the study. The pre- post achievement tests were administered to establish consistency within the First Control Group mean score without any technological intervention. They were instructed in the conventional manner. The outcomes were consistent with how geometry was conventionally taught and learned in secondary schools without the use of a Desmos graphing calculator.

Table 3: Paired Samples T-Test and Statistics of the First Control Group

		Mean	N	Std. Deviation	Sig. (2-tailed)
Pair 1	Pre-Effect of DGC on Learners' conceptual understanding	7.03	44	4.283	.271
	Post-Effect of DGC on Learners' conceptual understanding	7.55	44	2.935	

Source: Researcher, 2023.

Table 3 shows that the First Control Group's sample means (?) for the pre-post achievement tests were 7.03 and 7.55, respectively. Accounting for a difference of 0.52 based on mean scores. Additionally,individual score standard deviation (?) was 4.283 distance apart from each other's in the pre-test data set,and then in the post-test data set, they were reduced to 2.935. Therefore, since the calculated P-value (.271)is beyond the significance level (?=.05), we are unable to rule out the null hypothesis and say that there was no statistically significant difference improvement in learners' mental comprehension of geometry within the First Control Group at different testing periods.

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Analysis of the Second Control Group using Paired Samples T-Test Statistics

The data from the Second Control Group were examined using the statistics from the paired sampling t-test in Table 4. This demonstrated a comparison of the same group at various testing times. Form Two students in Kiambu County who took part in the study provided the information. To ascertain whether thereis consistency within the Second Control Group mean score without any technological intervention, the pre- post-achievement tests administered. They were instructed conventionally. The outcomes were consistent with how geometry is often taught and learned in secondary schools without the use of technological mathematics software applications.

Table 4: Paired Samples T-Test and Statistics of the Second Control Group

		Mean	N	Std. Deviation	Sig. (2-tailed)
Pair 1	Pre-Effect of DGC on Learners' conceptual understanding	9.25	44	5.230	.706
	Post-Effect of DGC on Learners' conceptual understanding	9.59	44	3.208	

Source: Researcher, 2023.

For the Second Control Group, the pre-post achievement tests sample means (?) were 9.25 and 9.59, respectively, in Table 4. Realizing a 0.34-point gap between the mean scores. Meanwhile, , the individual score standard deviation (?) was 5.230 wide apart from each other's, in the first test data set and then in the second test data set was 3.208 accounting for a 2.022 statistically increased. Since the calculated P-value (.706) is higher than the level of significance (?=.05), Because we are unable to prove the null hypothesis,we draw the inference that there was no statistically significant improvement in learners' conceptual understanding of geometry due to the absence of the Desmos Graphing Calculator.

Analysis of DGC Effect on Learners' Conceptual Understanding between the First Experimental Group and the First Control Group

In Table 5, shown the analysis was done between learners from both the First Experimental Group and the First Control Group because they were from the same Sub-County. The experimental group was taught using a Desmos Graphing Calculator, whereas the control group was taught using a traditional approach. Therefore, the study looked at how Desmos Graphing Calculator effect has on learners' conceptual understanding of geometry before and after the intervention. In this regard, Independent Samples T-Test and Groups Statistics were utilized.

Table 5: Independent Samples T-Test and Groups Statistics

	Treatment Groups	N	Mean	T-test for Equality of Variances Sig.	Sig. (2-tailed)
Pre-Effect of DGC on Learners' conceptual understanding	First Experimental Group	44	7.18	.087	.601
	First Control Group	44	7.03		
Post-Effect of DGC on Learners' conceptual understanding	First Experimental Group	44	45.89	.001	.001
	First Control Group	44	7.55		

Source: Researcher, 2023.

In Table 5, the sample means (μ) of both the First Experimental Group and the First Control Group were 7.18 and 7.03 respectively on the pre-test. Recording a 0.15 statistical difference in the mean scores. While 45.89 and 7.55 were the calculated sample mean (μ) for the post-test. This indicates that 38.34 statistical difference. Attempting the First Experiment Group difference of 38.71 mean scores (μ) between the pre-post testing sample means (μ) indicates a significant improvement in learners' conceptual knowledge of geometry after the use of the Desmos Graphing Calculator. As for the First Control Group, there was a 0.52 statistical difference pre-test versus post-test. In conclusion, the First Experimental Group overall sample mean (μ) was statistically 38.49 greater than the First Control Group's overall sample mean (μ).

In addition, since the Levene's Test P-value of the pre-test (.087) is greater than the Significant value (α=.05), we assumed that the variances are approximately equal while for the post-test (.001) is less than the Significant value (α=.05), we assumed that the variances are not approximately equal. Finally, since the calculated P-value (.001) of the post-achievement testis less than the degree of importance (α=.05), We find that the usage of the Desmos Graphing Calculator led to a statistically significant improvement in learners' conceptual knowledge of geometry, rejecting the null hypothesis.

Analysis of DGC Effect on Learners' Conceptual Understanding between the Second Experimental Group and the Second Control Group

Since both the Second Experimental Group and the Second Control Group were drawn from the same sub-county, both groups were included in the analysis in Table 6. The experimental group received instruction using a Desmos Graphing Calculator, while the control group received instruction using a traditional approach. Determining how the Desmos Graphing Calculator affects learners' conceptual grasp of geometry both before and after the intervention. In this regard, Independent Samples T-Test and Groups Statisticswere utilized.

Table 6: Independent Samples T-Test and Groups Statistics

	Treatment Groups	N	Mean	T-test for Equality of Variances Sig.	Sig. (2-tailed)
Pre-Effect of DGC on Learners' conceptual understanding	Second Experimental Group	44	9.70	.060	.642
	Second Control Group	44	9.25		
Post-Effect of DGC on Learners' conceptual understanding	Second Experimental Group	44	42.48	.001	.001
	Second Control Group	44	9.59		

Source: Researcher, 2023.

The sample means (μ) of the Second Experimental Group and the Second Control Group for the first test in Table 6 were 9.70 and 9.25, respectively. A statistical difference of 0.45-point in the mean scores is recorded. The computed sample means (μ) for the second test were 42.48 and 9.59, respectively. This suggests a statistical difference of 32.89. With a mean score differential of 32.78, the Second Experimental Group first test sample mean (μ) was less than the second test sample mean (μ) post use of the Desmos Graphing Calculator, and learners' conceptual knowledge of geometry increased significantly. For the Second Control Group, the pre-post testing statistical variation was 0.34. Finally, the Second Experimental Group sample mean (μ) was statistically 33.34 above that of the Second Control Group sample mean (μ) in total.

Furthermore, we considered that similar to the variations because the first test Levene's Test P-value (.642) is higher than the Significant value (α=.05). Although the post-test significance level (.001) was lower than the significant level (α=.05), we still inferred that the variances were not roughly equal. Additionally, Using the Desmos Graphing Calculator, we find that the null hypothesis is invalid which resulted in a statistically significant in learners' conceptual comprehension of geometry because the calculated P-value (.001) of the second test is less than the level of significance (α=.05).

Analysis of DGC Effect on Learners' Conceptual Understanding between the Experimental and Control Groups

The pre-post achievement test results were shown in Table 7's inferential statistics. The analyses were done using the test of homogeneity of variances, ANOVA, mean plots, and multiple comparisons between the treatment groups. Accounting for the groups, both groups received different treatments during the teaching of the geometry lessons. The experimental groups utilized a graphing calculator by Desmos while the control groups used the traditional teaching method to teach geometry.

Table 7: Descriptive Statistics of Experimental and Control Groups

		N	Mean
Pre-Effect of DGC on Learners' conceptual understanding	First Experimental Group	44	7.18
	Second Experimental Group	44	9.70
	First Control Group	44	7.03
	Second Control Group	44	9.25
	Total	176	8.29
Post-Effect of DGC on Learners' conceptual understanding	First Experimental Group	44	45.89
	Second Experimental Group	44	42.48
	First Control Group	44	7.55
	Second Control Group	44	10.32
	Total	176	26.56

Source: Researcher, 2023.

In Table 7, the pre-tests, results showed that the Second Experimental Group had the highest sample means (μ) of 9.70, followed by Second Control Group with 9.25, while the First Experimental Group and the First Control Group had 7.18 and 7.03. This means the Second Experimental Group performed the best among the groups, while the First Control Group was the least performed with a statistical mean score difference of 2.67.

Therefore, before the post-achievement test was administered, Desmos Graphing Calculator software was used to teach geometry lessons to the experimental groups. Thereafter, the results showed that the sample means (μ) of the First Experimental Group was 45.89, the Second Experimental Group B was 42.48, the Second Control Group was 10.32, and the First Control Group was 7.55. With a statistically significant score difference of 38.34, the First Experimental Group fared the best overall among the groups, while the First Control Group was the least effective.

Table 8: Test of Homogeneity of Variances of the Groups

		Levene Statistic	Sig.
Pre-Effect of DGC on Learners' conceptual understanding	Based on Mean	1.873	.136
Post-Effect of DGC on Learners' conceptual understanding	Based on Mean	19.216	.001

Source: Researcher, 2023.

Table 8 presents the pre-achievement test for homogeneity of variances. Therefore, since the P-value (.136) is higher than the significant value (α =.05), we assumed that variances are homogeneous amongst the obtained data set from the groups. While the P-value (.001) for post- achievement test is less than the significant value (α =.05), hence we assumed no homogeneity of variances among the data set obtained from the groups.

Table 9: ANOVA of the Experimental and Control Groups

		Sum of Squares	df	F	Sig.
Pre-Effect of DGC on Learners' conceptual understanding	Between Groups	261.841	3	4.900	.003
	Within Groups	3063.955	172		
	Total	3325.795	175		
Post-Effect of DGC on Learners' conceptual understanding	Between Groups	52913.562	3	500.168	.001
	Within Groups	6065.386	172		
	Total	58978.949	175		

Source: Researcher, 2023.

The analysis of variances (ANOVA) of the treatment groups shown in Table 9 was applied. With these, since both the pre-post achievement tests have P-values (.003) and (.001) and are less than the significant value (α =.05), we draw the conclusion that the difference is statistically significant between the levels of independent variables groups at each test toward performance. Also, since the pretest Effect size (n_2p=.079) is less than .14, there was no effect on the learners' performance. While the post-test Effect size (n_2p=.897) is larger than .14, then we conclude that there was a larger effect of their performances on achievement tests.

Pre-Test: F (3,172) =4.900, P<.003, n_2p=.079. Post-Test: F (3,172) =500.168, P<.001, n_2p=.897.

Table 10: Multiple Comparisons between the Groups' Achievement Tests

Dependent Variable	(I) Treatment Groups	(J) Treatment Groups	Mean Difference (I-J)	Sig.
Pre-Effect of DGC on Learners' conceptual understanding	First Experimental Group	Second Experimental	.477	.952
		First Control	3.182*	.601
		Second Control	.932	.729
	Second Experimental Group	First Experimental	-.477	.952
		First Control	2.705*	.066
		Second Control	.455	.958
	First Control Group	First Experimental	-3.182*	.601
		Second Experimental	-2.705*	.066
		Second Control	-2.250	.063
	Second Control Group	First Experimental	-.932	.729
		First Experimental	-.455	.958
		First Control	2.250	.063
Post-Effect of DGC on Learners' conceptual understanding	First Experimental Group	Second Experimental	3.409*	.059
		First Control	37.000*	.001
		Second Control	35.568*	.001

	Second Experimental Group	First Experimental	-3.409*	.059
		First Control	33.591*	.001
		Second Control	32.159*	.001
	First Control Group	First Experimental	-37.000*	.001
		Second Experimental	-33.591*	.001
		Second Control	-1.432	.671
	Second Control Group	First Experimental	-35.568*	.001
		Second Experimental	-32.159*	.001
		First Control	1.432	.671
Source: Researcher, 2023.				

Table 10 centered on comparing the pre-post testing on both occasions to determine the effect of the dependent variables on the treatment groups. This explained which group performed better than the others. Since the pre- achievement test P-values that existed between all groups are .952, .601, .729, .066, .958, and .063 and are all greater than the significant value (α =.05), considering this, we draw the conclusion that there was no statistically significant mean difference between the groups for the independent variables. In the post-achievement test, since the P-value (.001) established between the First Experimental Group and the First and Second Control Groups was less than the Significant value (α =.05), we can infer that the levels of the independent variable groups differed statistically significantly in the means.

Secondly, since the same P-values (.001) existed between Second Experimental Group and the First and Second Control Groups was less than the Significant value (α =.05), We can infer that the mean differences between the independent variable groups differed statistically significantly. Meanwhile, since the P-value (.059) was established between the First and Second Experimental Groups was greater than the Significant value (α =.05), we can draw the conclusion that the mean differences across the groups of independent variables are not statistically different. Thirdly, since the same P-value (.671) existed between the First and Second Control Groups was greater than the Significant value (α =.05), as a result, we can draw the conclusion that the mean differences between the groups of independent variables were not statistically significant.

We can infer from the post-achievement test multiple comparisons that the levels of independent variable groupings have statistically significant mean differences because the P-values that existed between the Experimental Groups and between the Control Groups (.001) are less than the Significant value (α =.05). That means there is a statistical mean variation between the groups with similar treatment.

To conclude, the usage of the Desmos Graphing Calculator in the experimental groups led to a statistically significant improvement in learners' conceptual comprehension of geometry when compared to the Control groups that were not exposed to it. The pre-achievement test relatively has had almost similar results because Desmos Graphing Calculator was not factored in for the learners' attention and attraction in their geometry lesson. Realizing when these two instances stepped in by visualization, the learners' conceptual understanding increased as recorded from the post-tests sample mean scores (μ) from the Experimental Groups.

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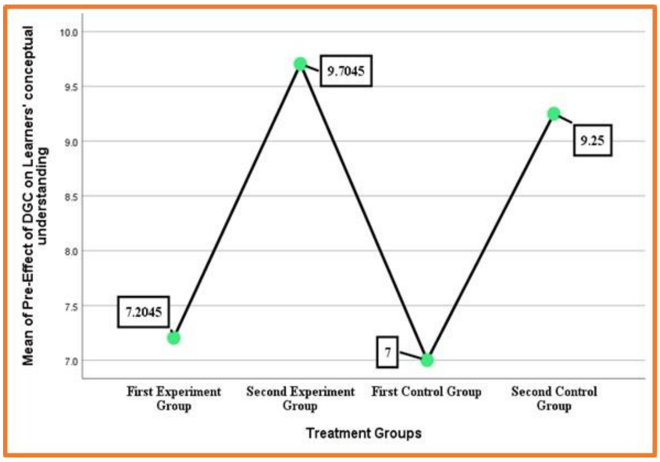

Figure 2: Mean Plot from the Pre- Achievement Test of the Treatment Groups

Source: Researcher, 2023.

Figure 2 of the pre-achievement test results clearly showed that learners of the Second Experimental Group performed best with the sample mean (?) score of 9.7, followed by Second Control Group with a sample mean (?) score of 9.25, and then the First Experimental Group with sample mean (?) score of 7.20. The First Control Group performed least among the treatment groups with its sample mean (?) score of 7.03.

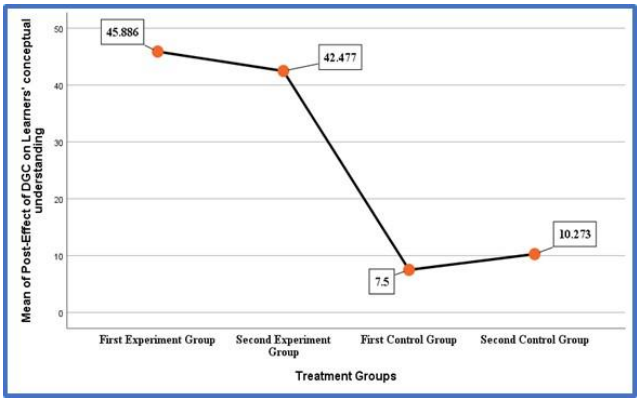

Figure 3: Mean Plot from the Post-Achievement Test of the Treatment Groups

Source: Researcher, 2023.

In Figure 3, the evidence presented is from the post-achievement test. The First Experimental Group performed the best among the groups with a sample mean (?) score of 45.89, followed by the Second Experimental Group with a sample mean (?) score of 42.48, and Second Control Group with a sample mean (?) score of 10.27. With a sample mean (?) score of 7.5 across the treatment groups, the First Control Group had the worst performance.

DISCUSSION

The study has the ultimate objectives of determining the effect Demos Graphing Calculator has on learners' conceptual understanding of geometry when used, teachers' and learners' preparedness to use it, and then learners' performances by gender.

As a result, the first finding indicates that using the Desmos Graphing Calculator has an impact on secondary school students' conceptual knowledge of geometry. Before this study, past studies (Juman et al., 2022; Maag et al., 2022; Gargrish et al., 2021; Tls& Herman, 2020) results seem like this study result that Desmos Graphing Calculator provides a platform for digital learning of virtualization and serve as a source of motivation. Meanwhile, somestudies(Machado et al., 2023; Makhdum et al., 2023; Jaafar et al., 2022; Glaze et al., 2021; Caniglia & Meadows, 2018) were concerned with the effects of using ICT as a learning resource in mathematics classes. According to the past research, DGC promotes the development of logical abilities, analytical thinking, and knowledge construction in learners as well as increases their retention of mathematical information in their cognitive memory. This study has found an almost similar effect. However, they diverge in terms of a particular geometry lesson taught in the secondary grades that was focused and the geometry strand of mathematics. Along with reviewing the students' attention spans and the appeal of the Desmos Graphing Calculator to them, the study also looked at teachers' attitudes and their methods of instruction.

In educational systems, for investments in the use of ICT in curricula to be successful, decision-makers and practitioners need to be adequately informed. The outcomes of this investigation are beneficial for improving students' comprehension of geometric ideas. Additionally, by acquiring new knowledge, it raises the bar of instruction for students by enabling them to appreciate the usefulness of technological instruments in geometry learning. Additionally, it offered reliable information that supports instructors' professional growth and the excellence of geometry instruction, two areas in which Desmos Graphing Calculator will be highly regarded. Investments can be targeted based on a instructors' behaviour, knowledge level, anddispense of knowledge in the education process. Furthermore, by reforming and refining educational policies, curriculum, teaching resources, government institution responsible for educational transformation, may find these results to be a significant proposal.

These findings supported the notion that when DGC is utilized by mathematics teachers to teachgeometry, it improves students' conceptual understanding. Finally, the study suggests DGC and should actas the basis for additional research because it makes a substantial contribution to the teaching and learningof geometry.

CONCLUSION

Based on the findings of this study, the followings conclusions were drawn:

The results of the study's pre-post testing demonstrated that learners in the First and Second Experimental Groups who used Desmos Graphing Calculators in the education process achieved higher geometry mean scores than those in the Control Groups were instructed using the conventional method. As a result, it makes sense to conclude that using the Desmos Graphing Calculator improves students' mental comprehension of geometry more than using traditional approaches. Additionally, the post-test findings showed a bigger effect rise in the Experimental Groups sample means scores than the pre-test, which is due to the use of the Desmos Graphing Calculator.

Teachers were trained for one week. Learners' attraction, retention, and conceptual understanding are primary goals for the geometry education. The study featured two Experimental groups that were taught about "Gradient, Equation, and Graph of a Straight Line" for three weeks using the Desmos Graphing Calculator software, and the identical lessons were imparted to the two Control groups using the conventional teaching technique.

RECOMMENDATION

The researcher has provided the following recommendations for stakeholders and other researchers based on the findings and conclusions of this study:

1. Mathematics teachers should consider using Desmos Graphing Calculator for teaching geometry in secondary schools. This has the potential to increase learners' conceptual understanding of the subject.
2. The Kenya Institution of Curriculum Development (KICD) ought to concentrate on including subject-specific ICT tools as one of the teaching strategies in the mathematics curricula of secondary schools.

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