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EFFECT OF TEACHING WITH GEOGEBRA ON SECONDARY SCHOOL STUDENTS' PERFORMANCE IN GEOMETRY IN KIAMBU COUNTY, KENYA

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ABSTRACT

Most secondary school pupils in Kenya need help to construct, visualize, and defend geometrical concepts despite the benefits of geometry as a subject. Children who receive education using this approach become passive learners with weak geometrical and analytical reasoning abilities. These challenges persist even though many pieces of software, including GeoGebra, have been developed to help teach and learn mathematics. Besides, few secondary school mathematics teachers in Kenya know how to use GeoGebra; most only know that it may be utilized.

On this basis, the current study sought to determine the effect of GeoGebra on geometry learning in secondary schools in the Ndeiya sub-county of Kiambu County, Kenya. The study objective was to determine the difference in geometry performance between students taught through GeoGebra and those through a conventional method. In addition, the study targeted 200 Form 2 students in public primary secondary school teachers in Ndeiya Sub-County, Kiambu County. A response rate of 184 respondents was attained, and data was gathered using mathematics achievement tests. The quasi-experimental Solomon four-group research design and independent t-tests were used to determine the effect of teaching with GeoGebra on secondary school students' performance in geometry. The ensuing findings showed that GeoGebra improved students' geometry performance. The study concluded that secondary school students taught through GeoGebra had better geometry performance than those taught through conventional approaches because the software enhanced their logical thinking, representation, abstract thinking, generalization, analytical thinking, and understanding of the subject.

Keywords: conventional approach, GeoGebra, geometry performance, traditional learning

INTRODUCTION

Education and technology immensely impact society's progress and people's lives. Technology in the classroom presents several advantages. It may inspire students to participate actively in their education, facilitate heuristic or experiential learning (Schuetz et al., 2018), and increase accessibility to education (Ianos & Brezeanu, 2020).

Like technology, geometry is interconnected with almost every part of mathematics; hence, learning and teaching geometry is indispensable. In addition to problem-solving abilities, learning geometry aids students develop conjecturing, deductive reasoning, intuition, imagery, logical argument, and proof skills (Armah et al., 2017). However, several concerns about children's geometric reasoning abilities have been raised, particularly at the primary school level (Armah et al., 2017). Accordingly, Armah et al. (2018) proposed that models should be employed in the instruction and comprehension of geometry for better learners' geometry reasoning abilities.

GeoGebra is a valuable tool that preservice teachers can employ to simplify the teaching and studying of geometry to learners in senior high school and those in primary school. According to Atebe (2008), countries including the US, the Netherlands, and Russia have revised or promoted their mathematics curricula to answer learners' concerns by integrating ICT into their tutoring. For instance, Kutluca (2013) found in his research that the experimental group that received GeoGebra instruction had a more significant increase in Van Hiele's geometry thinking levels than those taught with the traditional instructing circle technique. He said GeoGebra helped kids build, test, and refine their geometric shapes' comprehension. Alternatively, GeoGebra helped instructors treat their classroom as an exploratory milieu where learners actively engaged in the learning procedure by serving as an instructing and studying tool. In this situation, learners felt more at ease sharing their opinions, arguing the results with others, and improving their geometry comprehension.

Kutluca's (2013) study also attributed the comprehensive implementation of GeoGebra in the classroom to a boost in teaching and studying. Learners could delve into mathematical ideas and apply them to real-world instances with the aid of the application, which also assists them in better understanding how algebraic and geometric ideas relate to one another. The application is also linked to better visualization and demonstration, the creation of a supportive learning milieu, the preparation of teaching provisions using it as a tool for collaboration, communication, and representation, and helping students become more adept at calculating geometric transformations (Akgül, 2014; Vasquez, 2015). The software can also be used by students in elementary school through graduate school, starting with basic constructions and moving up to integrating features. While the learners can delve into mathematics independently or in groups, the teacher strives to serve as a guide in the background, helping as needed. From this perspective, for schoolchildren to learn and succeed in mathematics, it is essential to examine the effectiveness of GeoGebra-based training in geometry achievement.

Nonetheless, only a few research studies in Kenya discuss using GeoGebra as a teaching and studying apparatus for geometry. Consistent with Wambugu and Changeiywo's (2008) finding, a teacher's teaching approach is one factor that can influence learners' accomplishment, for using a suitable instructing aid is crucial to the effectual instructing and studying of mathematics. In this view, This study was designed to establish the effect of GeoGebra on geometry learning in secondary schools in the Ndeiya sub-county of Kiambu County, Kenya.

STATEMENT OF THE PROBLEM

The study aimed to tackle the problem of the conventional teaching practice comprising the talk-and-chalk style of instruction and its effect on geometry performance. In doing so, the study aimed to endorse using GeoGebra as a more effective tool in enhancing secondary school learners' performance. Notably, the traditional instructing and studying procedure has been associated with the inability of most secondary school pupils to construct, envisage, and defend geometrical concepts. This method also produces passive learners with weak geometrical and analytical reasoning abilities because it emphasizes memorization abilities more than the ability to think critically and rationally while also making the teachers the centre of attention.

Despite the shortcomings attributed to the conventional instructing style, this tactic remains commonplace in Kenyan secondary schools. Consequently, secondary school learners in Kenya face numerous challenges when learning geometry, negatively affecting their KCSE Mathematics exam performance.

These challenges persist even though many pieces of software, including GeoGebra, Mathematica, and Mat Lab, have been developed to help teach and learn mathematics. The most well-known of these is GeoGebra because it is easy to use and makes geometry fun. However, only some secondary school math teachers in Kenya know how to use GeoGebra; most only know that it may be utilized. On this basis, the current study sought to determine the effect of GeoGebra on geometry learning in secondary schools in the Ndeiya sub-county of Kiambu County, Kenya.

RESEARCH OBJECTIVE AND HYPOTHESIS

The objective guided the study:

i. To determine the difference in geometry performance between students taught through GeoGebra and those through a conventional method.

From this objective, the following null hypothesis was derived:

H_{01}: There is no difference in the geometry performance of students taught through GeoGebra and those taught through a conventional method.

LITERATURE REVIEW

In the community-supported mathematics studying environment known as GeoGebra, various dynamic representations, several mathematical subfields, and a wide range of modelling and simulation-related computing tools are all merged. Chimuka (2017) asserted that GeoGebra was more straightforward than a graphing calculator for a user-friendly design; GeoGebra offered multilingual menus, tutorials, and assistance.

Additionally, it offers numerous presentations, guided and unguided studying, and math projects. As a result, tens of thousands of people, including math professors and educators, come worldwide to use GeoGebra because of its user-friendly interface and web availability.

Existing literature also depicted GeoGebra as a top-notch educational program, a dynamic piece of software that can draw points, lines, and curves, and a fantastic choice for making presentations of diverse mathematical concepts. Tasman et al. (2018) asserted that GeoGebra can adequately, accurately, and exactly demonstrate abstract mathematical conceptions and afford dynamic drawing tools for the dynamic formation of various geometric forms, including points, vectors, line segments, lines, and polygons. Besides, learners are more engaged while employing applications in the classroom (Septian, 2017). By employing mathematical expressions, they can understand various geometrical ideas in a more imaginative, unique, inventive, energetic, and active way (Hallal et al., 2016).

To determine the efficiency of utilizing the GeoGebra application in learners' mathematics study in Malaysia, Nazihatulhasanah and Nurbiha (2014) studied the effects of GeoGebra on learners' success. They concluded that the software taught math more effectively than conventional classroom instruction methods. The authors agreed that using the software in math lessons more frequently was crucial for effectual education and long-lasting learning that improves achievement.

In a related study titled "The Effects of GeoGebra on Math Performance: Enlightening Coordinate Geometry Learning" (LV) by Royati, Ahmad, and Rohani (2010), the effects of employing the software on learners with high visual-spatial ability (HV) and low visual-spatial ability (LV) were investigated. The results demonstrated that employing computer-assisted studying on top of traditional classroom training enhanced student performance and was more operative than traditional instruction alone. This indicated unequivocally that the software was more efficient at teaching math than other tutoring strategies.

There was also evidence that employing technology in general and GeoGebra, in particular, promoted student achievement (Zengin et al., 2012; Zulnaidi et al., 2019). To investigate the program's effect on students' achievement in trigonometry, Zengin et al. (2012) used a control group that received constructivist training and an experimental faction that received teaching that included utilizing GeoGebra software. They found a significant achievement discrepancy between the experimental and control groups, with pupils using the application performing better than those not.

Additionally, the review demonstrated that technology may affect how kids feel about mathematics. Akanmu (2015) found a strong correlation between GeoGebra familiarity and attitudes toward mathematics among Nigerian students.

Two elements that may influence how learners feel about employing the application are their attitudes toward studying mathematics and their awareness of the software they use to study mathematical topics (Kele & Sharma, 2014). Anthony and Walshaw (2007) contended that students' attitudes toward technology should be a key concern when evaluating the sway of technologies on mathematics studying.

Generally, reviewing the literature on the effect of teaching with GeoGebra on students' geometry performance ascertained that the application was more effective at teaching math than other teaching strategies. Evidence indicated that employing the software enhanced students' achievement in trigonometry (Zengin et al., 2012) and their overall geometry performance (Hallal et al., 2016; Septian, 2017) and mathematics achievement (Zengin et al., 2012; Zulnaidi et al., 2019). Nevertheless, studies have not been carried out in Kenya, nor have they focused on Kiambu County. In addressing this gap, this study aimed to determine the difference in geometry performance between students taught through GeoGebra and those through a conventional method.

METHODOLOGY

The study adopted the quasi-experimental Solomon four-group research design to resolve teaching with GeoGebra's effect on secondary school learners' geometry performance in the Ndeiya sub-county of Kiambu County, Kenya.

Notably, the research divided the participants into four factions: two experimental and two control groupings. The first unit comprised an experimental faction with both pre- and post-tests. The second entailed a control faction that received both post-tests and pre-tests. The remaining two groups entailed a control group and an experimental group receiving only post-tests.

This study's target population was 200 form 2 students from four public primary secondary schools in Ndeiya Sub-County. All 200 participants formed the study's sample populace via census sampling. The study relied on two data-gathering apparatuses to amass data from the sample populace of 200 Form 2 public secondary institutes in Ndiaye Sub-County. The instruments entailed a mathematics achievement test (MAT) with questions about rotations. Four schools in the Ndeiya Sub County got the MAT. The control group entailed two schools, and the experimental encompassed the other two schools. One control and one experimental group got the pre-tests. After rotation teaching using the conventional tutoring approach of board, pen, and paper for the control groups and GeoGebra teaching for the experimental groups was finished, all the groups got the post-tests.

Data from the MAT findings were manipulated to calculate the mean of the pre-test and post-test of the control and experimental groupings. The two groups' means were compared utilizing the independent T-test to ascertain whether a statistically significant variance existed between the pre-tested groups and those that only received post-tests, as well as between the control and experimental groupings to resolve the effect of GeoGebra in secondary school students' geometry performance. The information obtained from the survey was evaluated and presented in tables and charts in conjunction with statistical averages and measures of dispersion.

Lastly, to ensure ethical research, the study observed several ethical considerations. Before kicking off the fieldwork, the researcher applied for a research permit with the Ministry of Education and the SCDE, Ndeiya sub-county and the National Commission for Science, Technology and Innovation (NACOSTI). Additionally, the researcher visited each of the schools that served as a sample for the study to explain the research goals, request that they allow their students to take the MAT, and request that one group of teachers use GeoGebra software to teach transformation while the teachers of the other grouping do not. Consent from the study's participants was obtained. The confidentiality of the collected data was also avowed to respondents. Lastly, students were not required to sign their names in the response booklets.

FINDINGS AND DISCUSSION

Response rate

The study sought out a sample populace of 200 Form 2 learners from four public secondary institutes in Ndeiya Sub-County. However, data was only amassed from 168 pupils, representing an 84 per cent response rate. According to Fincham (2008), a 60 per cent response rate and above is sufficient to generate reliable results. In this light, the 84 per cent response rate was adequate to produce reliable results to explain the effect of instructing with GeoGebra on secondary school learners' geometry performance in the Ndeiya sub-county.

Of the 168 student respondents, 84 were male whereas the remaining 84 were female, ensuring both genders were equally distributed within the respondents. Most of them (58 percent) were 15 years old, 37 percent were 16 years old, and 5 percent were 14 years old. These ages can be explained by the fact that the study targeted form 2 students. In Kenya, secondary education commences around 14, meaning that most form-two students are approximately 15 years old.

Solomon's four-group design was employed to settle on the difference in geometry performance between students taught through GeoGebra and those taught through a conventional method. In this light, the four schools in the study were randomly assigned to two experimental and two control groupings. Then, one control and one experimental group were pre-tested to determine whether students from both schools had the same academic ability in geometry before commencing the experiment. Afterwards, the experimental and control groups were subjected to the GeoGebra teaching approach and the conventional teaching approach (the board, pen, and paper approach), respectively. Lastly, all the groups were given a post-test.

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An independent t-test was conducted to compare the two pre-tested groups (one experimental and one control group). Table 1 below indicates the ensuing output.

Table 1: Comparison of Pre-test Mean Scores

	Treatment	N	Mean	Std. Deviation	S.E. Mean
Score	Control	42	5.14	2.53	.39
	Experimental	42	5.12	1.99	.31

Comparing the pre-test mean scores for the pre-tested control and experimental groupings showed no significant variance between the two groupings, as evidenced by 5.14 and 5.12 mean scores. These findings were further backed by the independent t-test outputs in Table 2 below.

Table 2: Independent Samples T-tests of Pre-test Mean Scores

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Score	Equal variances assumed	1.99	.162	.05	82.00	.962	.02	.50
	Equal variances are not assumed.			.05	77.65	.962	.02	.50

The 0.962 figure in the Sig. (2-tailed) in Table 2 were above the 0.05 significance level. This finding meant no statistically significant variations existed in mean scores between the pre-tested control and experimental groupings, suggesting a homogeneity in the two groups' geometric performance. Therefore, both groups had equal academic ability in geometry performance before administering the teaching interventions (conventional teaching for the control group and the GeoGebra teaching approach for the experimental group).

Independent T-test of Post-tests for the Pre-tested Groups

After confirming an evenness in geometric performance between the pre-tested groups comprising one control and one experimental grouping, an independent t-test of their post-test scores was computed.

Table 3: Comparison of Post-test Results for the Pre-tested Groups

	Treatment	N	Mean	Std. Deviation	S.E. Mean
Score	Control	42	6.14	2.68	.41
	Experimental	42	11.76	2.89	.45

Examining the respondents' mean results in Table 3 above verified a substantial difference between the two groups. The pre-tested control group's post-test mean score was 6.14, whereas an 11.76 mean score was found for the experimental grouping. The outcomes denoted that the experimental grouping had a notably higher mean score than the control grouping, suggesting a better geometry performance in the experimental group. Therefore, the study deduced that GeoGebra substantially improved students' geometry performance.

These findings were further confirmed by the findings in Table 4 below.

The p-values of 0.000, below the 0.05 significance level, verified a statistically significant difference in geometry performance between students taught through GeoGebra and those through a conventional method. Therefore, the study concluded that students taught through GeoGebra had a significantly better geometry performance than those taught through a conventional method.

Table 4: Independent T-test Results (Post-tests for the Pre-tested Groups)

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	**Sig.**	**T**	**Df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**
Score	Equal variances assumed	.03	.852	-9.24	82.00	.000	-5.62	.61
	Equal variances not assumed			-9.24	81.57	.000	-5.62	.61

Independent T-test of Post-tests (Post-tested Groups)

In testing and confirming the accuracy of the results in the preceding section, an independent t-test was computed based on the scores acquired from the two groups (one experimental and one control) that received post-tests only without partaking in pre-tests. Tables 5 and 6 show the independent t-test output.

Table 5 shows that the control group that received post-tests only had a 5.98 mean post-test score. The experimental group that partook in post-tests only had a 10.86 mean post-test score. The 4.88 mean difference between the groups indicated a substantially higher geometry performance among the students who were taught using GeoGebra compared to those who were taught using conventional methods.

Table 5: Mean Comparison for the Post-Tested Groups that Received Post-tests Only

	Treatment	**N**	**Mean**	**Std. Deviation**	**S.E. Mean**
Score	Control	42	5.98	2.32	.36
	Experimental	42	10.86	2.82	.43

The 0.000 p-values that were below the 0.05 significance level in Table 6 below depicted a statistically significant difference between the two groups. Therefore, these findings verified that there was a statistically significant difference in geometry performance between students taught through GeoGebra and those through a conventional method.

Table 6: Independent T-test Results for the Groups that Received Post-Tests Only

		Levene's Test for Equality of Variances		t-test for Equality of Means				
		F	**Sig.**	**t**	**Df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**
Score	Equal variances assumed	.66	.419	-8.67	82.00	.000	-4.88	.56
	Equal variances not assumed			-8.67	79.12	.000	-4.88	.56

Comparing the findings between the groups that received post-tests only and the ones that were pre-tested established that there was a significant difference between students taught using GeoGebra and those taught with conventional approaches. The students taught through GeoGebra outperformed those taught through the conventional method.

The results supported rejecting the null hypothesis: H01: There is no difference in the geometry performance of students taught through GeoGebra and those taught through a conventional method. These results indicated the efficacy of GeoGebra in enhancing students' geometry performance and the tool's superiority to traditional teaching methods.

Mahendra et al. (2019) associated GeoGebra with permitting students to utilize all their senses, including observing, seeing, hearing, and speaking, which could explain the software's efficacy in improving geometry performance. The efficacy of GeoGebra in improving secondary school students' geometry performance could also be linked to the fact that the software makes lessons more practical and accessible to comprehend (Narh-Kert & Sabtiwu, 2022). These findings are complemented by Chalaune and Subedi's (2020) study results, which perceived GeoGebra as an effective instrument to aid students in making clear sense of mathematical concepts and promote creativity and curiosity.

In addition, the software enhances students' visual representation ability by enabling them to construct geometric images that are 3 dimensional or 2 dimensional to epitomize accurate geometric shapes (Azizah et al., 2021; Kusmayadi & Fitriana, 2020). Lastly, GeoGebra has also been attributed to improving students' logical thinking, abstract thinking, and generalization. Therefore, secondary school students taught through GeoGebra have better geometry performance than those taught through conventional approaches because the software enhances their logical thinking, representation, abstract thinking, generalization, analytical thinking, and understanding of the subject.

CONCLUSION AND RECOMMENDATION

This study determined geometry performance differences based on the teaching approach adopted. The study concluded that students taught through GeoGebra had a significantly better geometry performance than those taught through a conventional method for the application afforded the students a better comprehension of geometry concepts, enhanced their visual representation and generalization abilities, and boosted their logical and abstract thinking. In this light, the study recommends that secondary schools in Kiambu County and other counties in Kenya integrate GeoGebra applications in mathematics classes to teach geometry.

As established in this study, this application's adoption would substantially boost the students' geometry and general mathematics performance and eradicate the trouble of passive learning and weak geometrical and analytical reasoning abilities linked to the conventional teaching approach. The study also recommends educating secondary school mathematics teachers on effectively using and implementing GeoGebra in their classrooms. This process should commence with raising the teachers' awareness of the application and its benefits in engaging students and enhancing their academic attainment.

Then, workshops, seminars, webinars, and forums should be set up to educate the teachers on implementing and using the application in their teaching.

Furthermore, the current study was constrained to Ndeiya Sub-County, Kiambu County, meaning that the findings could only be applied to this sub-county and generalized to Kiambu County. Thus, the findings might only be applicable in some Kenyan counties. In this light, future researchers on GeoGebra and geometric performance topics should focus on other counties or a collection of several counties to increase their generalizability of results to all secondary schools in Kenya. Finally, future researchers could benefit from gathering data from secondary school teachers to acquire their perspectives and insights on the effects of teaching with GeoGebra on their students' geometry performance.

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