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GeoGebra as a Tool for Improving Mathematics Instruction and Learning by Ghanaian Teachers

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ABSTRACT

This study is mainly about using GeoGebra as a tool for improving mathematics instruction and learning by Ghanaian teachers. The quantitative method was employed for the study and the descriptive statistics of the study were the mean, standard deviation, percentages, and frequencies were used. Two-way analysis of variance (ANOVA) was used in answering the Hypothesis test. The sample size for the study comprised 10 junior high schools and 13 primary schools. A total of 74 samples made of mathematics teachers were used of which 40 were junior high teachers and 34 were primary school teachers. A questionnaire with 10 questions/items with 4 options or 4 Likert scales for each was used in measuring the use of GeoGebra as a tool to improve mathematics instructions or learning by Ghanaian teachers (primary teachers and junior high school teachers). The study indicated that teachers believe that GeoGebra could effectively improve mathematics instruction and learning in the classroom. It also showed that teachers are ready to learn and adopt the use of technology (ICT) in their lesson delivery.

INTRODUCTION

The teaching and learning of mathematics in today's world goes beyond the traditional ways of teaching and learning. The use of ICT has become an integral part of our everyday living especially in the educational field. Many concepts in the learning and teaching of mathematics have become more enjoyable, understandable and easier through the use of ICT. As indicated by Mijares Benjamin (2022) and Lagura, (2022), ICT if effectively and adequately use in the teaching field plays important role in education.

In 2003, Ghana had its maiden edition of ICT week which assembled great and powerful academicians and experts in IT. In the second edition the major and the main focus of the ICT week was to embrace the role of ICT in the educational sector in helping to achieve the national development plan (ICT4AD, 2003). Yet an effective use or enforcement of the use of ICT in the teaching and learning of Mathematics from the basic level/pre – tertiary level is weak. This then informed the government in 2007 to reviewed the mathematics curriculum on ICT for Accelerated Development in the New Education Reform (MOESS, 2007). Even though there is the use of ICT in the teaching and learning of some subjects it is limited. This is because there is no strict supervision on the New Educational Reforms on ICT for Accelerated Development (ICT4AD, 2003) on instructional and learning process especially in the teaching and learning of mathematics (MOE, 2000). The use of technology (ICT) brings about conceptual understanding through pictorial representations in virtual, video, animation, graphics, and, etc (The American Association of Mathematics Teacher Educators, 2006). In view of this it very clear that the government of Ghana through the Ministry of Education is very much concern about the teaching and learning of Mathematics education through all levels in the country (MOESS, 2007). However, teaching and learning of mathematics as shown in most studies indicates that the achievement of pupils/students in mathematics are very low, since mostly used approach in the delivery of mathematics is teacher – centered strategy (Agyei & Voogt, 2011). Mathematics as a subject in our ordinary setting is perceived to be difficult. This is as a result of the approach used in its delivery. This approach by most of the teachers handling mathematics tends to have effects on the pupils/students understanding in the subject. As opined by Dariusz Majerek (2014) the teaching of mathematical concept without enough illustration, fixed mathematical graphs in explaining mathematical concept, generalization of concept that are fixed are the main barrels in teaching mathematics. In todays' dispensation or modern era, the process of teaching and learning of mathematics has become easier and enjoyable through the use of ICT (Technology). In the process of teaching and learning one of the resources which has become powerful is the use of technology (The American Association of Mathematics Teacher Educators, 2006). In teaching and learning of mathematics the use of technology (ICT) is very important during the instructional period. Mijares (2022), pointed out that the fast – facing trends in the educational system is a clear indication that teachers are to be trained and equipped themselves in the modern knowledge and skills in technology and pedagogy. Hence it is on all teachers to integrate technology in their classroom lessons. It has impact on the mathematics lesson/instruction and improves students learning. And among the six principles for school mathematics instructions, technology is one of the principles

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considered and accepted by National Council of Teachers of Mathematics the biggest association of mathematics teachers in the world (NCTM, 2000). Technology as resource in teaching and learning has come to stay in the academic settings and it environ (Museveni, 2006). In the process of teaching and learning of mathematics, a lot of technological software has been developed to help make it more appreciative and enjoyable. Notable among them are Mathematica, Sketchpad (Geometer), GeoGebra, Calculator, and, etc. GeoGebra is a mathematical software which was developed by Markus Hohenwarter in Austria (University of Salzburg) in 2001/2002 during his master's thesis. GeoGebra is a full package that links algebra, geometry and calculus together. It directly works with points, lines, segments, vectors, conic sections, shapes, and, figures (Hohenwarter & Jones, 2007). GeoGebra is interaction geometry, algebra, statistics and calculus application software intended for teaching and learning of mathematics at all levels of educational system. The importance of using GeoGebra in teaching and learning mathematics cannot be overemphasized as Danso-Ntow and Yunus (2021), asserted that in teaching concepts-based instruction, manipulative play a vital role. GeoGebra use in teaching circle theorem help students to understand the concepts and properties of circles making it easy for students to answer circle questions better compared to previous achievement. Again, Arbain and Shukor (2014), in their study on the effect of GeoGebra on students' achievement confirmed that the use of GeoGebra has positive impact on students' performance in that students actively participated in the lesson and willing to manipulates to find the end result which led to proper understanding. It is an undeniable fact by Majerek (2014), that GeoGebra software and its application in teaching and learning mathematics cannot be overlooked since it contributes to proper and easy understanding by students. He argues that it is important to include these electronic applications in our lesson delivery. Sangwin (2007), supported the idea that GeoGebra use as a tool for teaching and learning mathematics make plotting of graphs and shapes easy for students. He argues that even though GeoGebra plays a vital role in teaching and learning mathematics, teachers' knowledge on the application and it use is also very important because most of the mathematics teachers do not have the basic idea about the use of GeoGebra making it difficult for them to use in their lesson as agreed by Mokotjo & Mokhele (2021). This article looks into the use of GeoGebra in improving the teaching and learning of mathematics instruction by Ghanaian teachers. This investigation will help in knowing the impact of GeoGebra in classroom mathematics instruction and also know how knowledgeable teacher are in using during the instructional period.

Statement of the Problem

Chimuka (2017) examined the impact of using GeoGebra on the performance of South African students. Two groups of students on the same level were considered namely: the control group and the experimental class/ group. The experimental group was taught using the GeoGebra application software and the control group was taught by a teacher using the traditional chalk and blackboard method. After the data analysis, he concluded that the experimental group performed significantly better than the control group. Tetteh & Atteh (2022) also conducted a study on the use of GeoGebra software in teaching and learning transformation (rigid body motion) on Ghanaian high school student outcomes. Students were taught to solve conversion problems in the traditional way using chalk and a blackboard. After class, students were given a pre-intervention test, and researchers found that students performed poorly. The same group of students were taught using the GeoGebra application software. They were examined on the same question, and the results were relatively above average, confirming that GeoGebra makes it easy for students to draw graphics. Sangwin (2007) also supported the notion that technology (ICT) as a tool for teaching and learning mathematics, allows students to draw graphs and diagrams easily. Even though, GeoGebra plays an important role in mathematics teaching and learning most mathematics teachers do not have basic understanding or knowledge on how to use or apply it in their lessons as agreed by Mokotjo & Mokhele (2021). Although the use of GeoGebra in mathematics learning and teaching shows positive acceptance and perception, there is still uncertainty about how Ghanaian teachers view the impact of mathematics teaching and learning. The article looks into the use of GeoGebra in improving mathematics instruction and learning by Ghanaian teachers.

Research Question

This article investigates the use of GeoGebra as a tool for improving mathematics instruction and learning by Ghanaian teachers. The following are the primary questions that the study tries to answer:

1. Is there a common usage of GeoGebra as a tool for improving Mathematics instruction and learning by Ghanaian teachers (primary and junior high school teachers)?
2. What is the difference in the mean usage of GeoGebra as a tool for improving mathematics instruction and learning by Ghanaian teachers (primary and junior high school teachers)?

Research Hypotheses

The following hypotheses were given for the quantitative technique to answer the research questions. Null hypotheses (H0i) and alternative hypotheses (HAi) were used to designate the hypotheses, where i = 1, 2 and 3

$H_0$1: Null hypothesis: There is no significant difference in the mean usage of GeoGebra by Ghanaian teachers (primary and junior high school teachers) as a tool for improving Mathematics instruction and learning.

H_A1: Alternative hypothesis: There is a significant difference in Ghanaian teachers' mean usage of GeoGebra

as a tool for improving Mathematics instruction and learning (primary and junior high school teachers).

LITERATURE REVIEW

In examining the literature, we looked at many aspects of technology use in classroom instruction. These factors include: the role of technology in teaching and learning mathematics, Technology Beneficial in Student Learning, Technology Support in Discovery Learning, GeoGebra in Teaching Practice, and Student Engagement and Achievement Using GeoGebra.

The Role of Technology in Teaching and Learning of Mathematics

It is crucial that instructors and students have frequent access to technologies that support and promote mathematical sense making, reasoning, problem solving, and communication, as according to the National Council of Teachers of Mathematics (NCTM, 2000). Effective instructors make the most of technology's ability to deepen students' knowledge, pique their attention, and improve their mathematical skills. Teachers who wisely employ technology can increase all students' access to mathematics (NCTM, 2000).

Technology Beneficial in Student Learning

According to NCTM (2000), technology is significant in mathematics teaching and learning because it changes the mathematics taught and increases student learning. There is evidence that technology can enhance teaching (Dede, 2000). Using technology also assists students in developing visual pictures of mathematical ideas, organizing and analyzing data, and calculating more swiftly and precisely. Technology assists students in exploring all elements of mathematics, including geometry, statistics, algebra, measurement, and numbers (NCTM, 2000). Dynamic math software is one such technological instrument and some popular software includes Geometer's GeoGebra, Cabri, and Sketchpad.

Technology Support in Discovery Learning

Students may explore, discover, share, and engage with peers in an interactive learning environment made possible by the use of technology and dynamic software. GeoGebra, Geometer's Sketchpad, and Cabri are examples of dynamic applications that enable investigations that encourage the conjecturing process (Baki, 2005). According to research, kids become more motivated and acquire greater abilities when they can use technology to investigate and build their own understanding minimizing teacher – centered approach during instruction (Lagura, Rabang and Pascua, 2022; Lagura, 2022).

GeoGebra in Teaching Practice

GeoGebra is a dynamic system that combines geometry, algebra, and calculus. Markus Hohenwarter developed the free mathematics program GeoGebra in 2001 for his master's thesis at the University of Salzburg in Austria. On the official GeoGebra website, which also provides access to tutorials, the GeoGebra Wiki and the User Forum, associated publications, and details on local GeoGebra institutes, users may download the most recent version of the software (Sangwin, 2007). Users of GeoGebra, mostly instructors and students, can use this setting to investigate, clarify, and model mathematical ideas and their connections (Hohenwarter & Jones, 2007). GeoGebra connects many representations and takes algebraic, geometrical, and calculus instructions. Markus and his group of programmers created this software in a way to make the solving of mathematics easier. GeoGebra connects several representations and takes algebra, geometry, and calculus instructions. Markus and his team of programmers developed this software, which enables various representations and visualizations of mathematical topics.

Student Engagement and Achievement Using GeoGebra

Once more, Arbain & Shukor's (2015) study on the impact of GeoGebra on student achievement confirmed that the use of GeoGebra has a positive impact on students' performance in that they actively participated in the lesson and were willing to manipulate to find the end result, which led to proper understanding. According to Majerek (2014), it is inevitable that GeoGebra software and its applications in mathematics teaching and learning cannot be disregarded since they help students comprehend the subject matter correctly and make the case that it is crucial to integrate these digital tools into how we offer lessons.

METHODOLOGY

In this study the researchers look into the use of GeoGebra as a tool to improve mathematics instructions and learning by Ghanaian teachers. The study employed quantitative methods. The descriptive statistics, namely; the study's mean, standard deviations, percentages, and frequencies were obtained using the Statistical Package for the Social Sciences (SPSS) Version 16. Two – way analysis of variance (ANOVA) was used to analyzed the school level (primary and junior high schools) as a variable in two factor levels.

Sample

The sample size for the study consisted of 10 junior high schools and 13 primary schools within the Dormaa East Municipal. A total of 74 samples were used. 40 were junior high school teachers and 34 of them were primary school teachers.

Instrumentation

A questionnaire with 10 questions/items with 4 options or 4 Likert scale for each was used in measuring the use of GeoGebra as a tool to improve mathematics instructions or learning by Ghanaian teachers (primary teachers and junior high school teachers). The scale included four

options: 1 for strongly agreeing, 2 for agreeing, 3 for disagreeing, and 4 for strongly disagreeing. In line with the study objectives and the research hypothesis, the questionnaire was created to address three primary areas: emotional outcomes of using GeoGebra, experience and instruction with GeoGebra, and instructors' beliefs about the cognitive impacts of using GeoGebra.

RESULTS AND DISCUSSIONS

Results

Under this section we look at the research questions and research hypotheses of the study. The statistical analyses of the data collected are also presented.

Results of the Statistical Analyses

The study employs descriptive statistics to examine the level of teacher agreement over the usage of GeoGebra in teaching mathematics. 74 teachers were used for the study of which the number of females and males form the primary level were 42 and 10 respectively. However, 6 females and 16 males were from the junior high school. In all a total of 52 females and 22 males were used for the study.

There were 4 – point Likert scale on the questionnaire. The information obtained from the Consensus of Teachers' in using GeoGebra in mathematics instruction was entered into SPSS version 16 as shown in Table 1 below.

Table 1: Consensus of Teachers' in using GeoGebra in mathematics instruction.

Questions (Item)	Frequency	Percent	Nature
When a lesson is taught with GeoGebra, they don't need to show their work on paper.	61	82.4	Disagree
The use of GeoGebra in Mathematics instructions makes it easier in solving problems.	51	68.9	Agree
Students understand mathematics better if they solve problems using paper and pencil	52	70.3	Agree
Teachers should not be permitted to utilize GeoGebra in their classrooms unless they have mastered the idea or technique.	60	81.1	Agree
GeoGebra should be learned by all mathematics teachers.	63	85.1	Agree
The GeoGebra program is available in the school for my class(es) to utilize.	54	73.0	Disagree
Almost 90% of instructors have access to their own GeoGebra software suite.	49	66.2	Disagree
I have previously utilized GeoGebra in my classroom.	68	91.9	Disagree
I understand how I can properly use GeoGebra in my classroom.	49	66.2	Disagree
I have several ideas on how I can use GeoGebra.	51	68.9	Disagree

Source; Field survey, 2023

According to Table 1, 81.1% of instructors believe that teachers should not be permitted to use GeoGebra in class until they have mastered the subject or method. Many instructors (85.1%) thought that all mathematics teachers should learn to use GeoGebra. An overwhelming majority of teachers (91.9%) have never used GeoGebra in their classroom. However, 66.2% of the teachers do not know ways they can use GeoGebra effectively in the classrooms.

On students understanding mathematics better when they solve problem using paper and pencils 70.3% agreed. 82.4% of mathematics teachers disagreed that when a lesson is taught with GeoGebra, they don't need to show their work on paper. Although 68.9% of the mathematics teachers agreed that the use of GeoGebra in Mathematics instructions makes it easier in solving problems in mathematics. 73.0% disagreed that there is availability of the GeoGebra software in the school for my class(es) to use.

Research Question One

Is there a mean use of GeoGebra as a tool for improving Mathematics instructions and learning by Ghanaian teachers (primary and junior high school teachers)?

Using a 4-point Likert scale the instrument had a 0 to 3 item range. This was then entered into SPSS version 16 to obtain the frequencies (N), the mean and the standard deviation. The values for the mean and standard deviation are shown in Table 2.

So according Table 2, the mean and standard deviation for 48 female instructors using GeoGebra as a tool to improve mathematics and learning were 1.48 and 0.83, respectively. The mean and standard deviation of the 26 male instructors on the usage of GeoGebra to improve mathematics instruction and learning were 1.40 and 0.90, respectively. However, in terms of levels, the mean for primary school teachers on the use of GeoGebra as a tool for improving mathematics and learning was 1.55 with a standard deviation of 0.91, while the mean and standard deviation for junior high school teachers were 1.38 and 0.86, respectively. The mean and standard deviation for the entire teachers on the use GeoGebra for improving mathematics instruction and learning was 1.44 and 0.90 signifying neutrality or slightly positive acceptance.

Table 2: Means and standard deviations of Ghanaian teachers' usage of GeoGebra as a tool for improving mathematics instruction and learning.

Primary school	N	Mean	Standard deviation
Male	10	1.44	0.82
Female	42	1.47	0.92
Total	52	1.55	0.91
Junior high school			
Male	16	1.37	0.91
Female	6	1.43	0.66
Total	22	1.38	0.86
All			
Male	26	1.40	0.90
Female	48	1.42	0.83
Total	74	1.44	0.90

Source; Field survey, 2023

Research Question Two

What is the difference in the mean use of GeoGebra as a tool for improving mathematics instruction and learning by Ghanaian teachers (primary and junior high school teachers)?

Table 2 indicates that out of the 74 teachers a mean of 1.55 and standard deviation 0.91 representing 52 teachers from the primary schools who handles mathematics believes that GeoGebra as a tool for improving mathematics education and learning is the finest.

However, 22 junior high school mathematics instructors had a slightly favorable or neutral impression of GeoGebra as a tool for boosting mathematics instruction and learning, with a mean of 1.38 and standard deviation of 0.86. As a result, there is no difference in the mean of Ghanaian instructors (primary and junior high school teachers) when GeoGebra is used as a tool to improve mathematics instruction and learning.

The research presented above indicates unequivocally that Ghanaian teachers would welcome any attempt by policymakers to incorporate GeoGebra into mathematics education and learning.

Hypotheses Testing

In a two – factor analysis of variance, the study used school level (primary and junior high schools) as a variable. The item range of the instrument was 0 – 3.

The hypothesis was as follows:

$H_0$1: There is no statistically significant difference in Ghanaian teachers' mean usage of GeoGebra as a tool for improving Mathematics instruction and learning (primary and junior high school teachers).

H_A1: There is a substantial difference in Ghanaian teachers' mean usage of GeoGebra as a tool for improving Mathematics instruction and learning (primary and junior high school teachers).

Table 3: Variance Analysis for Teachers Using GeoGebra to Improve Mathematics Instruction and Learning

Source	Sum of Squares	Df	Mean Square	F
School level	0.66	1	0.66	0.80
Error	58.82	72	0.82	
Total	59.48	73		

Source; Field survey, 2023

Thus, according to Table 2, the mean and standard deviation for 52 primary mathematics instructors were 1.55 and 0.91, respectively, while the mean and standard deviation for 22 junior high school mathematics teachers were 1.38 and 0.86, respectively. However, there is no significant difference in the mean usage of GeoGebra as a tool for improving Mathematics instruction and learning by Ghanaian teachers (primary and junior high school teachers) based on the ANOVA test findings shown in Table 3, F (1, 72) = 0.80. We cannot reject H01 since the estimated F (0.80) is smaller than the F table (2.79). As a result, there is no significant difference.

Discussion

The descriptive analysis of the data that addressed the usage of GeoGebra as a tool to improve mathematics instruction and learning by Ghanaian teachers (primary and junior high school) was marginally favorable. Despite the fact that the majority of teachers lack experience and access to the package. There were just as many instructors who were enthusiastic about using GeoGebra in their classroom.

In this circumstance, it may be possible to conduct an awareness program to assist instructors in developing their capacity to utilize ICT in teaching mathematics

lessons in order to modify the attitudes of teachers who have a negative view of the usage of GeoGebra. It should be noted that Ghanaian teachers' proclivity for using GeoGebra does not appear to contradict the academic literature on the function of teacher attitude in technology integration in mathematics instruction and learning.

According to NTCM (2000), the teacher is the most important element known to impact student learning. In this regard, the mathematics instructor should have positive attitudes about mathematics as well as the utilization of resources such as GeoGebra to make mathematics entertaining and engaging to children. The minor manifestation of positive sentiments among Ghanaian instructors might be regarded a step in the right direction.

About (85.1%) believed that all mathematics teachers should learn to use GeoGebra. This indicate that Ghanaian teachers seems to be positive irrespective of the level agree in the use of GeoGebra as a tool in mathematics instruction and learning. As a result, a movement in policy favoring GeoGebra in mathematics instruction and learning might have a beneficial influence on teachers' perceptions of GeoGebra use, therefore improving mathematics instruction and learning.

According to the data, even though a significant majority of instructors (91.9%) have never used GeoGebra in their classroom instruction, 68.9% of teachers feel that using GeoGebra in mathematics instruction makes it simpler to solve issues mathematically.

The two-way analysis of variance found that there is no significant difference in the mean usage of GeoGebra as a tool for improving Mathematics instruction and learning by Ghanaian teachers (primary and junior high school teachers), $F(1, 72) = 0.80$. We fail to reject H01 because the computed F (0.80) is less than the F table (2.79), implying that there is no substantial difference.

CONCLUSION

Technological advancement has made a significant impact to all aspects of our life. Educators are concerned with how to integrate technology into classroom in order to increase the quality of mathematics instruction while simultaneously improving student performance.

Ghanaian instructors have said that, while they do not presently teach with GeoGebra, they believe that using GeoGebra may significantly improve mathematics education and learning in the classroom.

In this view, policymakers should abandon their easy stance and develop policies that raise awareness of the critical role GeoGebra plays in mathematics education and learning as a technology tool. This knowledge would pave the way for the development of a worldwide uniform instructional technology strategy, especially increasing teacher attitudes toward and ultimate acceptance of GeoGebra in mathematics instruction and learning.

Conflicts of Interest

Authors declare no conflicts of interest.

Data Availability

Data for the study can be made available upon genuine request.

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Authors' Contributions

The study was carried out in collaboration between all authors. Author PAAM and EA came out with the design of the study, performed the statistical analysis and the analyses of the study, wrote the first draft and protocol of the manuscript. Authors IBK and JGJ worked and managed the literature. All authors read and approved the final manuscript before submission.

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