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Use of GeoGebra to improve Performance in Geometry

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Abstract

The main purpose of this study was to use GeoGebra in the teaching and learning of Geometry among mathematics education students as well as in-service teachers, using an action research approach. The purposive sampling technique was used to select two public tertiary institutions for the study. The sample size consisted of 150 students comprising 51 from the University of Ghana and 99 from the University of Education, Winneba. Pre- and post- test design, involving teacher-made tests, were used during the experiment to collect data on the samples used. The paired samples t-test and analysis of covariance were used to analyse the scores of tests. The finding showed that there is a statistically significant improvement in the students' scores and interest in the learning, as well as the teaching of Geometry. Also, the GeoGebra method made the lessons more practical and easier to understand. It is therefore recommended that mathematics teachers should incorporate GeoGebra in the teaching and learning of Geometry.

Keywords GeoGebra; circle theorem; teaching geometry

Introduction

Geometry is connected to Mathematics in almost all areas and its teaching and learning cannot be overlooked in any way. The study of geometry helps students develop problem-solving, conjecturing, deductive reasoning, intuition, visualization, logical argument and proof (Armah, Cofie & Okpoti, 2017; Alex & Mammen, 2016). Mathematics Education students in Ghana are part of the pre-service teachers being trained in all tertiary institutions and the pedagogical and content knowledge of pre-service teachers is so vital that it goes a long way in training the up-and-coming workforce of the nation and for that reason, all efforts are made in making sure it is done well.

Some of the geometry topics for these mathematics education students are; lines, angles, polygons, congruent and similar triangles, geometrical construction including loci, circle theorem, 2D shapes and 3D objects, movement geometry and coordinate geometry which also have direct bearings in the mathematics curriculum for basic schools including senior high schools. The teacher in any educational setting is seen as someone who possesses specific and adequate content and pedagogical knowledge for teaching. The traditional approach to learning geometry focuses more on recall than on improving students' reasoning abilities. According to Van Hiele (1999), the Euclid logical construction of geometry with its axioms, postulates, definitions, theorems, and proofs was admirable for mathematical achievement Baffoe & Mereku (2010), but also stressed that school geometry that is taught in the traditional Euclidean ways with the aim that the students think on a formal deductive level is not always the case Baffoe & Mereku (2010). According to (De Villiers, 1997; Hiele, 1999) students find it difficult with

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geometry when it is presented in the Euclidean approach to them, Baffoe & Mereku (2010). Studies have revealed that pre-service teachers lack the geometric thinking skills required to teach at basic schools (Halat & Sahin 2008; Halat, 2008). According to Armah et al (2017), the situation is no different from the Ghanaian perspective. Only a few studies have been embarked upon in Africa, especially in Ghana.

Several studies notably (Halat & Şahin 2008; Ndlovu, 2014; Armah, et al, (2017) have indicated that teachers at all stages need the experience to attain the content knowledge for effective mathematics instruction. Numerous concerns have been raised on the levels of students' geometric thinking in Ghanaian schools, most especially at the basic school (Anamuah-Mensah & Mereku, 2005; Armah, Cofie & Okpoti, 2017; Baffoe & Mereku, 2010). Armah, et al, (2018) noted that models should be used in the teaching and learning of Geometry. Geogebra is a powerful tool that can be used to make the teaching and learning of geometry easy with both the pre-service teachers who will intend to use it for both basic school learners and senior high school learners according to Halat & Şahin (2008), teachers' content knowledge is vital to students' performance because if the knowledge of the teacher is not sufficient then it will lead to poor performance. According to Atebe (2008), countries like the U.S.A, the Netherlands, and Russia have advocated or reformed their Mathematics curriculum to solve students' problems by doing away with the Euclidean formal axiomatic geometry. As a result of the constructive-based approach of the current Mathematics curriculum, teaching and learning of Mathematics has improved substantially due to the accessibility of educational technology (National Council of Teachers of Mathematics, 2003). Confirmations from literature show that teachers who utilize educational technology comprehensively in their Mathematics instruction environment are likely to build high confidence in pedagogical technology skills and focus their lessons on a student-centred approach which improves students' performance in Mathematics (Bos, 2009). This will help guide students to explore and visualize Mathematics, especially geometrical concepts. The use of ICT in education permits learners to involve in certain cognitive activities such as carrying out scientific procedures, studying natural phenomena through simulation, looking up information, analysing data and solving real-life problems (Anamuah-Mensah, Mereku, & Asabere-Ameyaw, 2004).

However, despite the impact of educational technology and strong advocacy for the need to utilize ICT in the teaching and learning of mathematics, classrooms in Ghana are still characterized by the traditional methods of teaching. The traditional method is the teaching approach characterised by lecture/oral exposition. This teaching approach is more of teacher-centred rather than learner-centred. GeoGebra is one of the educational technology tools used in mathematics instruction and any other subject. This software was developed by Markus Hohenwarter at the University of Salzburg in the year 2001 as his master's thesis. It is a Dynamic Mathematics Software (DMS) for Mathematics instruction and is simple to use since it offers basic features of Computer Algebra Systems (CAS) to link some gaps between Algebra, Calculus and Geometry. GeoGebra is open-source software under the GNU General Public License and freely available at www.geogebra.org (Majerek, 2014).

Of all the ICT-based lessons, the dynamic software, GeoGebra has been newly used to create the visual and dynamic interaction in teaching and learning Mathematics

(Hohenwarter & Fuchs, 2004). This software has made it possible for students to discover theorems about circles by dragging a point on the circumference of a circle with the mouse. GeoGebra motivates learners to approach Mathematics with an experimental method (Hohenwarter & Fuchs, 2004).

For instance, Kutluca (2013) found out from his study that GeoGebra instruction employed on the experimental group was better on increasing Van Hiele geometry thinking levels of students than the traditional approach of teaching circle. He indicated that GeoGebra helped students in creating their own geometric shapes, testing and constructing their own knowledge. GeoGebra, as both learning and teaching tool, also helped the teachers to change their classroom to an investigative environment whereby students were actively involved in instructional process. More so, students learning in such an environment were able to contribute their thoughts at ease, argue the results with colleagues and make their individual understanding of Geometry (Kutluca, 2013). It is obvious from Kutluca's (2013) study that when GeoGebra is fully utilised in the classroom, it will enhance better teaching and learning.

Also, Bhagat and Chang (2015) used a quasi-experimental research design to survey "the effect of using GeoGebra, on student's Mathematics attainment in learning Geometry" among fifty students divided into an experimental and a control group. The experimental group was taught using GeoGebra while students in the control group were instructed through a traditional teaching approach. Bhagat and Chang (2015) observed in their work the difference in the mean achievement scores of students taught with GeoGebra and that of students taught with the traditional method. It was again revealed that students' cognitive and visualization skills improved tremendously. Again, GeoGebra facilitated the learners in the demonstration of mathematical ideas in diverse way, which can influence students to learn Mathematics. It is clear from the study of Bhagat and Chang (2015) that teaching and learning Geometry with GeoGebra, helped students to improve their reasoning, visualization skills and representation of mathematical concepts in diverse ways. Notwithstanding, this software is a better option for schools in rural areas where Internet connection is a problem.

A study conducted by Mwingirwa and Miheso-Connor (2016) on "status of teachers' technology uptake uses of GeoGebra in teaching secondary school Mathematics in Kenya" through training thirty-three Mathematics tutors on GeoGebra use. They also tried to implement what teacher had learnt from the training. The outcomes from Mwingirwa and Miheso-O'Connor's (2016) work uncovered that the prepared educators appeared to be excited about utilizing GeoGebra in their classes. This was because GeoGebra instruction in their classes enabled students to grasp difficult and unique concepts in Geometry and also saved teachers time whereby they were able to cover the syllabus more effectively. The outcome of Mwingirwa and Miheso-O'Connor's study also pointed that GeoGebra was the most appropriate software or teaching-learning resource for teaching Geometry due to its abstract nature. They also found out that teachers usually had trouble teaching geometry when they were solicited to demonstrate areas from mathematics, they discovered hard to teach. The instructors accentuated these challenges they experienced because of the absence of resources for teaching geometry and students' failure to envision geometrical objects. The study was, therefore, guided by the research questions: What is the difference in performance between pre-service teachers taught using GeoGebra and those taught using the traditional method?

While it is promising to see that several previous studies have demonstrated positive effects of GeoGebra instructional approach lessons on students' achievement, a reading of the literature available indicates that many of these studies are not centred on GeoGebra instructional approach in teaching and learning Circle Theorems as a sub-topic under Geometry, particularly in Ghana. Also, the findings of the study pointed to the challenges teachers faced in teaching Geometry to the lack of resources to teach Geometry, its abstract nature and the inability of students to visualize geometrical images. Therefore, it is the aim of this study to determine the effects of using GeoGebra as an instructional tool in teaching Circle Theorems on the performance of SHS 2 students. This will enable students visualize geometric images in the GeoGebra interface and discover the properties about the circle.

Methods

The action research approach was employed using tests in ascertaining the use of GeoGebra in improving the teaching and learning of geometry among mathematics education students in two public universities in Ghana. The action research was used because, the writers in their teaching experiences see teaching as a cyclic process and not a product, in that, during teaching and learning, different materials may be used, different methods may be employed, and different skills may be explored but the desired result may not be achieved and therefore, other different approaches may be required. This may begin another cycle of exploration to achieve the full potential of learners which can go on for some time. On trying to improve the teaching and learning of geometry in mathematics, the target population of this study was the mathematics education students in the university of Ghana and University of Education, Winneba. Besides the purpose of using GeoGebra to improve the understanding of geometry among the student teachers, there can be a collaboration between the two universities in improving teacher education in Ghana and comparing the results from both universities for further studies. Purposive sampling techniques were used to select 150 students for the study.

The participants were made to download the GeoGebra app which was a free application software. They were led into how to use the software. GeoGebra is a dynamic mathematics software for all levels of education that brings together geometry, algebra, spreadsheets, graphing, statistics, and calculus in one engine. The software GeoGebra originated in the master's thesis project of Markus Hohenwarter at the University of Salzburg in 2002 (*Kovács, Zoltán; Parisse& Bernard (2013).* The GeoGebra approach was used in teaching participants in the experimental group for the period. Upon constant use of the software, the participants exposed to the software (i.e., the experimental group) and those taught without it (i.e., the control group) were given the same test items.

There were 10 items for both the pre-test and the post-test testing the understanding of geometric concepts. The items were on the identification of lines and shapes; the naming of lines and shapes such as triangles, squares, circles and rectangles. There were questions too on recognizing and naming properties of geometric shapes and figures. Some items dealt with questions that require students' understanding of the significance of deduction and the role of postulates, axioms, theorems and proof. Both scripts were marked, recorded, and analyzed.

Results

What is the difference in performance if any, between student teachers taught using GeoGebra as a tool and student teachers taught using the traditional method of board and marker?

Table 1 gives a descriptive statistic of the results from the pre-test and the post-test administered.

Table 1 Descriptive statistics of the performance (N = 150)

Test	Minimum	Maximum	Mean	Std. Deviation
Pre-test	9	14	11.00	1.853
Post-test	15	19	17.11	1.347

Table 1 compares the pre-test and post-test results of the mathematics education students sampled. The results showed an improvement in students' understanding of teaching and learning geometry. The minimum score students obtained in the pre-test was 9, while the maximum score was 14 out of 20. However, in the post-test, the minimum score was 15, while the maximum score 19 out of 20. The mean score of students in the pre-test was 11.00, while that of the post-test was 17.11. This is an indication that in the post-test, every student's performance had increased. This improvement in scores might be due to the use of the GeoGebra approach to teaching and learning geometry since the course was on the premises that, the students already had exposure to geometry.

The box plot in the next section elaborates on the median scores of both the pre-test and the post-test that are not shown on Table 1.

From Figure 1, it could be seen that the median mark for the pre-test score is 12 whilst the median mark for the post-test is 17 with an average difference of 5. This is an indication that the mathematics education students performed better with a better understanding of geometry with the use of GeoGebra. A paired samples t-test was conducted to ascertain whether or not the differences recorded in the means of the results obtained in the pre-test and post-test were statistically significant. Table 2 presents the results of the paired samples t-test on the pre-test and post-test performance of the sample.

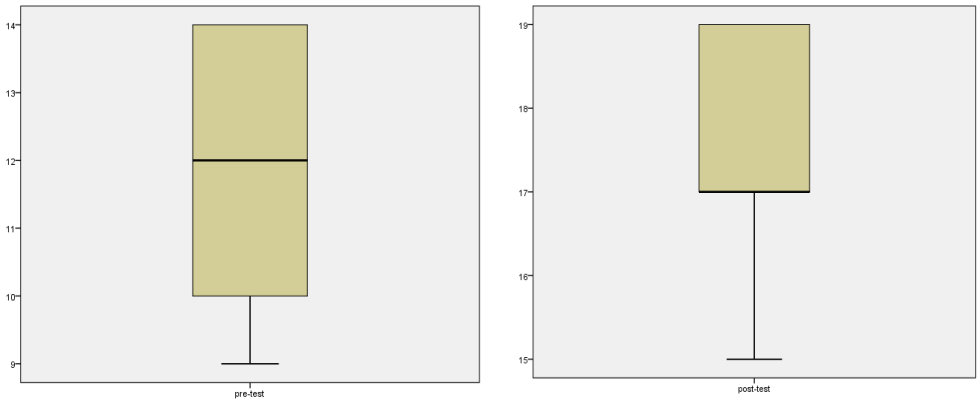

Figure. 1

Table 2 Results of the paired samples t-test on the pre- and post- test performance

Test	Mean Difference	Std. Deviation	Std. Error Mean	*t*	*df*	Sig.
Pre-test – Post-test	5.147	1.458	0.119	43.231	149	.0001

When a paired sample t-test was conducted to compare the pre-test and post-test scores for the students to check if the differences recorded earlier with the descriptive is statistical significance, there was (M = 5.147, SD = 1.458) between the post-test and the pre-test. The results from Table 2 indicate a statistically significant increase in the student's achievement from the pre-test and the post-test, with $p < 0.0001$. Also, the results imply that after the students had gone through the intervention, they improved massively in their understanding and achievement of the basic concepts in Geometry, giving a clear indication that, if these mathematics education students graduate and go to their classrooms in both the junior high schools and the senior high schools, they will create an impact in the teaching and learning of mathematics.

Discussion

The traditional approach of learning geometry which focuses more on recall than improving students' reasoning abilities was seen to be working with the Euclid logical construction of geometry with its axioms, postulates, definitions, theorems, and proofs which were admirable for mathematical achievement some years back. In the wake of emerging technology for visualization and better understanding with the industrial revolution of education 4.0 in Ghana (Narh-Kert, Osei, & Oteng, (2022) there is a need to move from the traditional way of chalk and board in teaching geometry to using GeoGebra.

It was observed during the intervention period that, throughout the time when the GeoGebra was being used to teach and learn geometry, the interest of the students was sustained. It was so engaging that, the average time of 2hours per session during the intervention was not enough making students continue with the exploration after the class.

Conclusion and Recommendations

The findings from the study indicate that if Mathematics Educators are engaged in the teaching and learning of geometry using GeoGebra software as an instructional tool, their performance would be better. This is because, GeoGebra makes lesson more practical, easy to understand, interesting and also enhances students' visualisation instead of memorisation of theorems. Also, it will go a long way for the mathematics education students who will be going to teach to also experience the use of the Geogebra as a technology use in teaching and learning of Mathematics. The observation made during the intervention period that, throughout the time when the GeoGebra was being used to teach and learn geometry, the interest of the students was sustained and was so engaging that, the average time of 2 hours per session during the intervention was not enough making student continue with the exploration after the class is a good act and must be carried out to the basic school classrooms The study, therefore, concludes that GeoGebra is one of the solutions to improve the performance of mathematics education students as well as students in both junior and senior High schools who are taught mathematics by students of mathematics education on completion. It is therefore recommended that,

mathematics education students in all tertiary institutions including colleges of education students specialising in mathematics to use the geogebra app in teaching and learning of mathematics especially geometry. Also, seminars/workshops should be organized for In-service Mathematics teachers on the use of appropriate technological tools such as GeoGebra in the teaching and learning of mathematical concepts by experts in the teaching universities. This is because the application of GeoGebra in teaching and learning requires skills on the part of teacher.

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