Original Research Article

THE IMPACT OF USING GEOGEBRA SOFTWARE IN TEACHING AND LEARNING RIGID MOTION (TRANSFORMATION) ON SENIOR HIGH SCHOOL STUDENTS' ACHIEVEMENT

ABSTRACT

This study looked at the impact of using GeoGebra to enhance the teaching and learning of transformation in senior high schools in Ghana. The difference in performance of students when taught using the traditional method and when taught with the help of this innovation was the main objective of the study. However, the students' performance in answering rigid motion (transformation) questions and their views about the use of the innovation was also assessed before and after the intervention respectively. The design adopted for this study was a mixed methods design of qualitative and quantitative approaches. The instruments for data collection were test items and interview. The target population was SHS two science classes of the New Juaben Senior High School and the population size was hundred and nineteen (119) whilst the sample size was forty-five (45), comprising two (2) classes, which was selected based on simple random sampling. In the pre-intervention stage, a pre-test was used to identify the weaknesses of the students before the interventional strategies were applied. A post-test was conducted to evaluate the intervention strategies, and interview was conducted afterwards. The data obtained was analyzed with the help of descriptive and inferential statistics for the uptake of technology. The study results presented a clear indication that GeoGebra had helped improve the students' understanding of concepts in transformation and hence improve performance. Due to the effectiveness of using GeoGebra in learning, students wish it would be used in teaching other mathematics topics. The study recommends that mathematics teachers should adopt and employ technology applications in teaching different mathematics concepts as it facilitates students' achievement in mathematics.

Keywords: *Rigid motion; transformation; GeoGebra; geometry; teaching and learning maths*

INTRODUCTION

Mathematics occupies a privileged position in the school curriculum since the ability to cope with it improves one's chances of social advancement. In Ghana, students are admitted into the tertiary institution based on their performance in the West Africa Secondary School Certificate Examination (WASSCE). A pass in mathematics in the Senior Secondary School Certificate Examination (SSSCE) or the West African Senior Secondary Certificate Examination (WASSCE) is a basic requirement for admission into the tertiary institutions in Ghana. This is required irrespective of the program of study the student wishes to pursue. Hence the study of mathematics in Ghanaian schools. This implies that students who lack

mathematical competence will find many doors leading to a productive as well as successful future closed.

In the High school levels of study, the mathematics syllabus includes Geometry. The branch of mathematics that has the closest relationship to the world around us, as well as the space in which we live is geometry. Adolphus (2011) describes geometry as an aspect of mathematics which deals with the study of different shapes. These shapes may be plane or solid. It is believed that, learning geometry in schools gives a natural environment in which students' reasoning and judgment abilities improve (Ersoy 2003). Therefore, understanding the principles of geometry is a must for courses in science, arts, and technology (Özgür & Taş 2019; Mifetu, Kpotosu, Raymond, & Amegbor 2019).

Rigid motion of the plane is a motion which preserve distance. According to Mashingaidze (2012), transformation can be divided into two areas, isometries and non-isometries. Isometries include Translation, Reflection and Rotation. Whereas non-isometries include enlargement, Shear and Stretch. The isometries (translation, reflection, and rotation) preserve the distance between vertices of any polygon. Thus, rigid motions are transformations that create congruent figures. The idea that all points in the plane move can be shown using technology; thus, students are able to see that there is a direct relationship between transformations and the distance from the segments and the points that make up the line of reflection point of rotation or direction of transformation of figure being transformed (Hollebrands, 2003).

The factors that are responsible for students' performance and achievement in mathematics are teacher factor, student factor and environmental factor. The teacher factors include subject mastery, instructional techniques and strategies, classroom management, communication skills, and personality. The student factor comprised of study habits, time management, attitude and interest in mathematics; the environmental factor includes issues such as parents' values and attitudes, classroom settings, and peer group. These are confirmed by a study of Yilmaz, Altun & Olkun (2010) which suggested that, factors that influence students' attitudes towards Mathematics are the teaching materials used by teachers, teacher's classroom management, teacher content knowledge and personality, teachers' ability to relate the topics with real life situation.

Despite the benefits of geometry most senior high school students are unable to construct, visualize and justify geometrical concepts due to traditional approach of teaching and

learning process in Ghanaian classrooms (Adolphus, 2011). This method of teaching makes students passive listeners and deficient in geometrical analysis and reasoning. Also, this approach to teaching and learning Geometry lay more emphasis on how much a student can remember and less on how well the student can think and reason, and it makes the teacher dominate the classroom and turns students to mere listeners (Mereku, 2010). The method used in teaching by teachers is very necessary as this affects the interest of students in the subject. Supporting this, Emaikwu (2012) reported that teaching method affects the response of students and determines whether they are interested, motivated and involved in a lesson in such a way as to engage in learning.

However, research indicates that students have difficulties in understanding the concepts and variations in performing transformations (Akay, 2011; Yazlık, 2011; Ada & Kurtulus, 2010; Acquah & Alhassan, 2018; Gürbüz, 2008; Rollick, 2009). In a similar fashion, Ghanaian senior high school students are faced with varieties of difficulties relating to geometry and for that matter rigid motion of transformation hence their performance in the topic continue to decline (WAEC, 2012; WAEC, 2014; WAEC, 2015). There are many possible reasons for this, a typical example is the traditional talk-and-chalk teacher-centred type of teaching, which assumes that students are passive recipients of knowledge is not in exception (Chimuka, 2017).

The problem then is what must be done differently to assist the students to improve on their understanding, knowledge and skills as well as acquiring new principles as the study looked specifically at the mathematical content of rigid motion in the Senior High School syllabus. The intention of the study was to investigate whether it is worthwhile to integrate GeoGebra into the teaching and learning process in order to narrow the instructional and knowledge gap, seemingly created by the teacher factor (teaching aids). Moreover, the traditional talk-and-chalk teacher-centred type of teaching, which assumes that students are passive recipients of knowledge, has lost its lustre among technologically savvy youths (Chimuka, 2017). It is one's belief that the integration of information technology (IT), GeoGebra in particular, into the teaching and learning of secondary school mathematics can serve as a scaffold on which changes and developments in curriculum can be better managed (Mwingirwa, 2012).

Research questions

The following questions guided the researcher to undertake this study;

1. What is the effect of teaching rigid motion using GeoGebra on SHS students' achievement?
2. What are the views of students about using GeoGebra in learning rigid motion?

LITERATURE REVIEW

Theoretical Framework

Technology acceptance depends on how it is perceived, how the participants create and share the information with one another, the period and how conducive the environment is. Hence, this study was guided by Diffusion Innovation Model (DIM) adopted by Rogers. Diffusion is the process by which an innovation is communicated through a certain channel over time among the members of social systems (Rogers, 1995). DIM is a theory that seeks to explain how, why, and at what rate new ideas and technology spread through cultures. It explains four main elements that influence the spread of a new idea. These elements include; Innovation, Communication channel, Time and Social system.

According to Rogers (2003), "An innovation is an idea, practice, or project that is perceived as new by an individual or other unit of adoption". An innovation may have been discovered a long time ago, but if individuals perceive it as new, then it may still be an innovation for them. In the view of Rogers (2003), communication is "a process in which participants create and share information with one another in order to reach a mutual understanding" (p. 5). This means that, interpersonal channels of communication are more powerful which can easily create or change strong attitudes held by an individual. It is argued that including the time dimension in diffusion research illustrates one of its strengths (Rogers, 2003). For researchers to measure the innovation-diffusion process, adopter categorization, and rate of adoptions all include a time dimension. Rogers (2003) defined the social system as "a set of interrelated units engaged in joint problem solving to accomplish a common goal" (p. 23). Diffusion of innovations takes place in the social system; hence it is influenced by the social structure of the social system.

The diffusion process determines the success or failure of any new product in the market. The theory notes the part played by attitude of people when it comes to adapting to new technology. Roger's theory advocates that innovations diffusion is a process that takes time to occur.

Technology in teaching and learning of mathematics

Almost all of mathematics syllabi clearly states that a mathematics course is designed to enable the learners acquire attitudes and knowledge that will be relevant to his or her life after school. To achieve this, great emphasis is placed on the application to real life situation and practical approaches to the teaching and learning of the subject, a fact which can be seen from mathematics books in primary schools and secondary schools (Mwingirwa, 2012). Teachers should focus on fostering the students' understanding of mathematical concepts and they should provide a quality education environment for them. For learning to take place, students need to be actively engaged with the explored concepts or objects – whether abstract or concrete (Liang & Sedig, 2010). Nevertheless, research study has proved that when teachers integrate technology appropriately into the learning process, student motivation and student achievement levels increased (Engel & Green, 2011).

It is believed that integrating ICT into our everyday teaching and learning can provide creative opportunities for supporting students' learning and fostering the acquisition of mathematical knowledge and skills (Hohenwarter & Hohenwarter, 2009). Similarly, the use of technology in the classrooms in today's world is believed to have a positive effect on students' success and their attitudes towards mathematics lessons (Ramadan & Hüseyin, 2014). In a mathematics classroom, the strategic use of technology strengthens mathematics teaching and learning (Dick & Hollebrands, 2011). Findings from a number of studies have shown that the strategic use of technological tools can support both the learning of mathematical procedures and skills as well as the development of advanced mathematical proficiencies, such as problem solving, reasoning, and justifying (e.g., Gadanidis & Geiger, 2010; Nelson, Christopher, & Mims, 2009; Pierce & Stacey, 2010; Roschelle, et al., 2010; Suh & Moyer, 2007). Due to the proven importance of technology in teaching and learning across the world, the integration of ICT is an essential agenda of the government of Ghana to raise standards in schools and promote teachers' and students' access, skills and knowledge to new technologies. They believe technology can be used to restructure and redesign the classroom to produce an environment that promotes the development of higher-order thinking skills (Kurt, 2010).

Effect of GeoGebra on Mathematics learning

GeoGebra is a community-supported open-source mathematics learning environment that integrates multiple dynamic representations, various domains of mathematics, and a rich variety of computational utilities for modelling and simulations. According to Diković

(2009), in comparison to a graph calculator, GeoGebra is more user-friendly. GeoGebra offers easy-to-use interface, multilingual menus, commands and help. Besides, encourages students` projects in Mathematics, multiple presentations and experimental and guided discovery learning. GeoGebra is also noted for its friendly interface and its web accessibility making it attract tens of thousands of visitors across the world that includes class room mathematics teachers and mathematics educators.

Nazihatulhasanah and Nurbiha (2014) conducted a research on "The effects of GeoGebra on students' achievement "in order to investigate the effectiveness of using GeoGebra software on Mathematics learning among students in Malaysia. Their findings concluded that GeoGebra is very helpful in the mathematics classroom teaching and more effective than traditional teaching method. The researchers agree that making more use of GeoGebra in mathematics teaching is a factor in effective mathematics teaching and permanent learning that improves performance. In a similar study by Royati, Ahmad and Rohani (2010) on "The Effects Of Geogebra On Mathematics Achievement: Enlightening Coordinate Geometry Learning" to examine the effects of using a free-software called GeoGebra in the learning of Coordinate Geometry among students classified as high visual-spatial ability students (HV) and low visual-spatial ability students (LV). The findings showed that computer assisted instruction as a supplement to traditional classroom instruction is more effective and improves students' performance than traditional instruction alone. This clearly demonstrates the instructional effectiveness of GeoGebra as compared to the traditional construction tools.

METHODOLOGY

Research Design

A mixed method design comprising of both qualitative and quantitative research designs was used for this study. Teddlie and Tashakkori (2009) concur that the mixed method research provides better inferences and minimizes the biasness that occur during the use of one method. The type of mixed method used was sequential explanatory. A sequential explanatory design consists of first collecting quantitative data and then collecting qualitative data to help explain or elaborate on the quantitative results (Plano Clark, 2011). Mixed method is the best paradigm of research because it eschews the use of metaphysical concepts that has caused much endless discussion and debate and also presents a very practical and applied research philosophy (Bryman, 2012, Teddlie and Tashakkari, 2009, Regmi, 2010).

Population and Sampling

The population of the study comprised of students in the New Juaben Senior High School in the Koforidua municipal. The school has a population of two thousand five hundred and twenty-three (2523) students. In this study, sampling was done at two levels. First, the Form 2 class was selected purposively. Form two students were selected due to the fact that they were expected to have covered some prerequisites in Geometry from the Form 1 mathematics content. Purposive sampling was used to select the two science classes in form 2, with a population of hundred and nineteen (119) students. Simple random sampling was then used to select 45 students for the study. Six volunteers from the students were interviewed. Students partaking in the interview were selected based on their performance in the Post-test. The average age of the class was seventeen (17) years and the students came from various regions in Ghana.

Research Instruments

This study was done using test items and interview. The pre-test examination for the sampled students were administered in order to establish the learners' level of knowledge. Post-test was done after exposure of students to rigid motion using GeoGebra for the same group to establish if there was a statistically significant difference in their performance before and after using GeoGebra. Additionally, interview was conducted for some selected students after the post-test to find out their view about GeoGebra in learning transformation geometry in order to address the second research question.

The instruments were validated by three experts in the field of mathematics and ICT, at University of Education, Winneba, Ghana. A trial test was conducted to establish the internal consistency of the instruments using Crombach Alpha reliability technique and reliability coefficients of 0.76, which was an indication that the instruments were reliable.

Intervention Activities

Due to the poor performance of the students in the Pre – test, the authors outlined series of instructions for the intervention. There were four (4) major interventional activities which the students were taken through to grasp the concept of Transformations in geometry using GeoGebra app. The students were guided to perform;

1. Drawing of basic shapes under transformation. The students were given a step-by-step guideline on drawing these basic shapes (polygons).

2. Translation of Objects under transformation. The students were taken through a series of activities to learn this concept.
3. Reflection of objects under transformation. The students were assisted through a series of instructional activities to complete some learning tasks on reflection.
4. Rotation of geometrical shapes under transformation. The students were taken through a step-by-step guideline to complete some learning task on rotation of shapes (polygons).

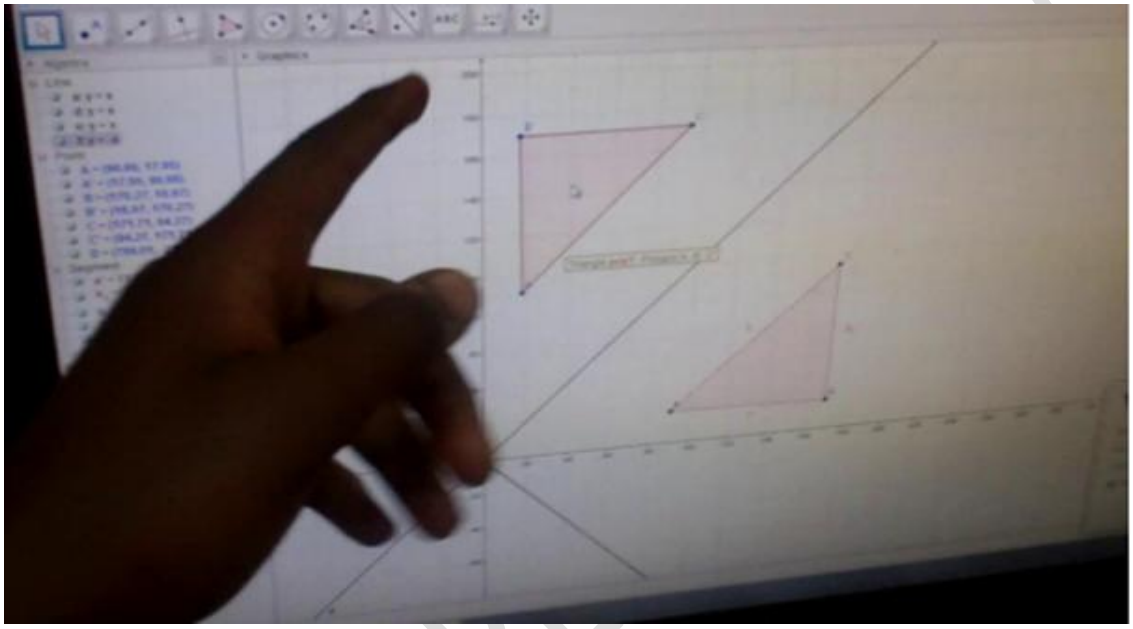

Figure 1: Simple basic reflection on GeoGebra along the line *x=y* form classroom activities

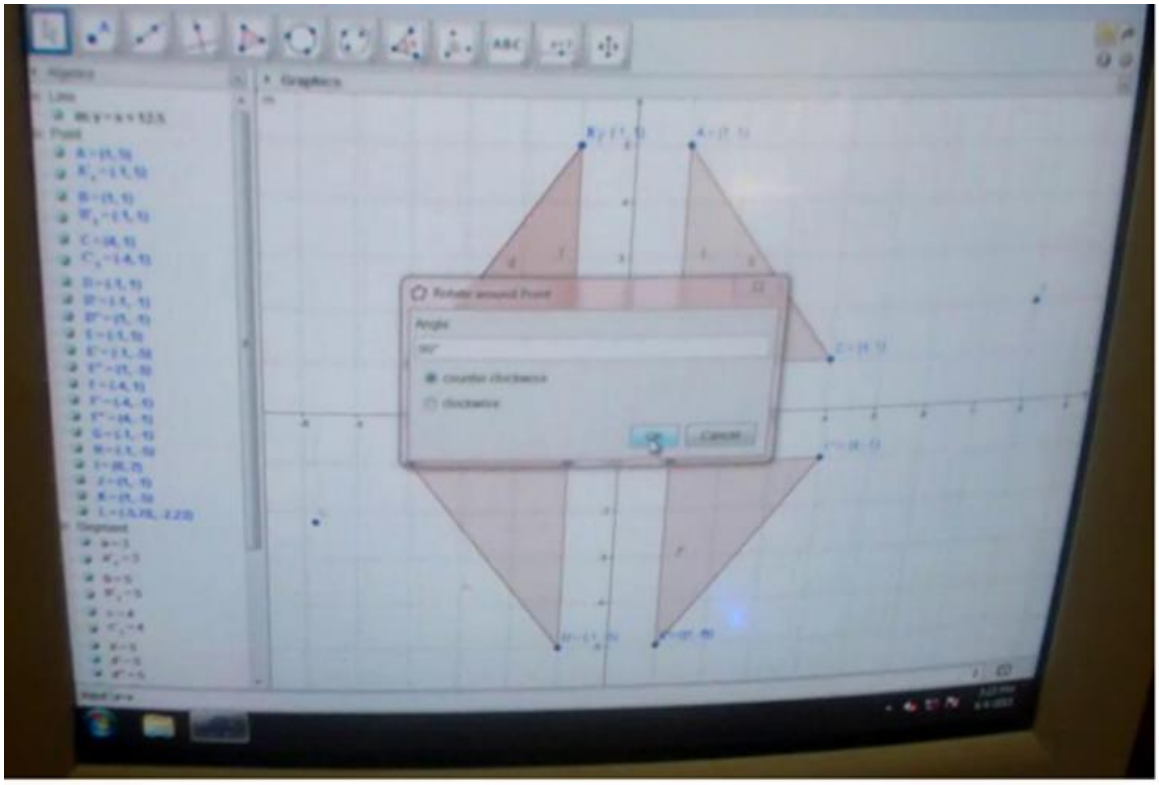

Figure 2: A rotation of a figure with the origin as the center of rotation at an angle of 90˚ from classroom activities

RESULTS AND DATA ANALYSIS

The study produced both quantitative data and qualitative data, showing scores of students in the pre-test and the post-test. Students' achievement test scores were analyzed using inferential statistics. Specifically, the t-test was executed using the Statistical Package for Social Sciences (SPSS) version 20 software. The t-test was used to test for statistical significance difference between the pre-test and post-test scores of the participants. Descriptive statistics (percentages, mean and standard deviation) was used for the analysis of scores. Students' interview responses were transcribed and analyzed to answer the second research question.

The effect of teaching rigid motion using GeoGebra on SHS students' achievement

To respond to the first research question, the study sought to compare scores of students in the pre- test and the post-test examinations involving rigid motion. Table 3 indicates the mean and standard deviation of the paired samples.

Table 1: means of Pre-test and Post-test

Paired	Mean	Number	Std Deviation
Pre-Test	13.6	45	5.9
Post-Test	25.0	45	3.9

From Table 1, the results indicated that the average scores were higher for the Post-test scores as compared to the pre-test. The pre-test produced (M=13.6, SD=5.9) as against the post-test (M=25.0, SD=3.9), there is therefore an increase in students' rigid motion achievement after the instruction with GeoGebra software.

To find out if the difference in means is significant, paired sample T-test was conducted as shown in Table 2.

Table 2: Paired T-Test analyses of means

	Mean	Std Deviation	T	Df	Sig (2-tailed)
Pre-Test& Post Test	-1.1	5.8	-13.1	44	0.0000

A paired-samples t-test in Table 2 indicated a test statistic of -13.1 and a p-value of 0.000 with 44 degrees of freedom. The two-tailed p-value of 0.000 is far less than the conventional 0.05 level of significance. There is therefore enough evidence to conclude that, there is a significant difference between students' pre-test and post-test mean scores. The results suggested that the GeoGebra software increased students' achievement in rigid motion (transformation) under geometry.

The views of students about using GeoGebra in learning rigid motion

Students general view about using GeoGebra in learning rigid motion (transformation) were collected through an open-ended interview after the implementations. The opinions of the six (6) students who participated in the interview are presented in the Table 3.

Table 3. Student's opinions about the use of GeoGebra software

Student Number (S)	Students' opinions about the use of GeoGebra software
1	Using GeoGebra have helped me to understand this difficult topic in an easy way. It has also built my confidence in mathematics.

2	I love the use of GeoGebra because this has given me opportunity to do mathematics with computer. Moreover, this has helped me in building confidence to learn mathematics since I was actively involved.
3	I enjoyed the mathematics lessons when taught using GeoGebra software. The use of GeoGebra software did not only engage me, but also helped me to develop interest in learning mathematics.
4	The GeoGebra software aided me to answer the questions correctly; it was because I was actively involved in the lesson; it is a very effective software.
5	The GeoGebra software enabled me to build a connection between the concepts and the physical representations within my minds which in turn motivated me to learn rigid motion of transformation geometry.
6	I learnt more when engaged with technology as I felt comfortable learning with the GeoGebra software. I wish it would be used in teaching other mathematics topics.

The Table 3 revealed students' positive opinions about the use of GeoGebra software which includes enjoyment, building confidence, developing interest in learning, better understanding of concepts, the wish to learn other topics through the use of the software, and improving active involvement in lessons which lead to better performance in the subject.

DISCUSSION OF RESULTS AND FINDINGS

The results of the present study justified that incorporation of GeoGebra app in learning help students learn transformation more effectively as they provide students with an authentic environment to learn and practice in a stimulating way. The students when exposed to GeoGebra achieved a higher average score compared to their scores during the pre-test. The study revealed that there was an increase in the learning achievement of the students in transformation under geometry after the use of GeoGebra app in the learning process. This is in line with studies conducted by Engel and Green (2011), MacBride and Luehmann (2008) and Shirley et al., (2011) which confirmed that when teachers integrate technology appropriately into the learning process, student motivation and student achievement levels increased.

GeoGebra-generated sketches are neat and accurate. GeoGebra allowed students real-time exploration opportunities. Consequently, this improved the learning process in terms of speed and quality (Ljajko and Ibro, 2013). When students learn using GeoGebra they spend less time drawing diagrams (sketches) and making calculations; this allows them more time to explore the characteristics of different geometric figures. All these factors contributed to the superior achievement of the participants in the post-test.

Further, the finding from the open-ended interview reveals that using GeoGebra in teaching and learning not only increases students' achievement in general, but also motivates them. All six participants in the interview affirmed that GeoGebra enhanced their motivation to learn transformation, lesson was interesting which got them participating actively, the software was effective, the software aided them to answer the given examples correctly, and they wish it would be used in teaching other mathematics topics. Research provides extensive evidence of GeoGebra having positive motivational effects on geometry students (BECTA, 2013) in the form of increased participation in class activities, improved concentration in class, enjoyment during learning times, self-confidence, content mastery and ultimately recommendation of this teaching and learning method.

This suggests that using GeoGebra can facilitate and promote learning, understanding, thinking, visualization in the mind, seeing details, internalization and recall. In this connection, Dikovic (2009) stressed that GeoGebra can provide many opportunities for students to visualize the mathematical process and acquire an intuitional viewpoint. Furthermore, these views concur with the statements of high school students found in the study conducted by Zengin et al (2010) using activities and applications developed through GeoGebra. The high school students stated that they use GeoGebra willingly and enthusiastically, the information they learned previously by memorizing can be retained more easily when visualized by using GeoGebra, the program enhances visualization and provides a discovery-based learning environment enabling them to recognize the relationships between mathematical concepts.

In summary, the findings of the study clearly showed that, the students who went through the learning process with GeoGebra enhanced their understanding of rigid motion (transformation) concepts. It was confirmed that GeoGebra was able to build a connection between mathematics concepts and the physical representations within their minds. All the aforementioned findings disclose that the use of GeoGebra app in learning facilitated in bringing improvements in the learning scores of students in transformation. Therefore, due to the effectiveness of using GeoGebra in learning, students wish it would be used in teaching other mathematics topics.

CONCLUSION AND RECOMMENDATIONS

The study concludes that GeoGebra is one sure tool which can aid the improvement of performance in problems involving transformation and for that matter geometry concepts as it

enhances understanding which is key to good mathematics learning at secondary school level. Again, the evidence in this paper shows that technology has a positive effect on student learning expectations and outcomes. To reiterate, technology integration has the following benefits: 1) increased student motivation; 2) increased student engagement; 3) increased student collaboration; 4), increased hands-on learning opportunities; 5) increased confidence in students, and 6) increased technology skills. The use of variety of technology applications helps students' in understanding the subject better compared to conventional styles. Thus, better and higher accomplishment could be continued and the act of seeing mathematics as a difficult subject will be reduced.

The study recommended that;

- Mathematics teachers should adopt and employ technology applications in teaching different Mathematics concepts as it facilitates students' achievement in mathematics.
- There should be regular in-service training for mathematics teachers to ensure that they are in touch with modern teaching methods in line with the changing times.
- It is also important for Mathematics teachers to align the teaching styles to the learning needs of the students for the effective and consistent delivery of the lessons.

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