

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. A mixed methods design combining qualitative and quantitative approaches was used for this study. 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. Descriptive and inferential statistics were used to analyze the data for the adoption of technology. The study's findings made it abundantly evident that GeoGebra had improved students' knowledge of transformation principles and, consequently, their 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 has a special place in the school curriculum since mastering mathematics increases one's chances of social development. In Ghana, a student's performance in the West Africa Secondary School Certificate Examination (WASSCE) determines whether they will be admitted to a tertiary institution or not. A student must score at least a "C6" or better in Mathematics in the WASSCE in order to be admitted to a tertiary institution. Suggesting that a pass in mathematics in 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. Geometry is the area of mathematics that is most closely related to our physical environment and the area where we live. Geometry, according to Adolphus (2011), is a branch of mathematics that deals with the investigation of various geometrical shapes. These shapes could be solid or plane. 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. Isometries and non-isometries are two categories under which transformation can be separated, according to Mashingaidze (2012). Translation, reflection, and rotation are examples of isometries. While enlargement, Shear, and Stretch are examples of non-isometries. The distance between any polygon's vertices is preserved by the isometries. Rigid motions are hence transformations that result in congruent figures. Students are able to see that there is a direct correlation 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 because technology can be used to demonstrate the idea that all points in the plane move (Hollebrands, 2003).

The factors that are responsible for students' performance and achievement in mathematics are teacher factor, student factor and environmental factor. The instructor factors include subject expertise, methods and strategies for teaching, classroom management, interpersonal and communication abilities, and personality. The environmental component includes elements like parental values and attitudes, educational environments, and peer groups. The student factor consists of study habits, time management, attitude, and interest in mathematics. These are supported by research from Yilmaz, Altun, and Olkun (2010), which found that teaching materials, classroom management, subject knowledge, personality, and the capacity to connect content to real-world situations are all elements that affect students' attitudes toward mathematics.

Despite the benefits of geometry as a topic, the majority of senior high school students in Ghana are unable to construct, visualize, and defend geometrical concepts because of the

traditional teaching and learning methods used in the classrooms (Adolphus, 2011). Students who are taught using this method become passive listeners who lack the ability to analyze and reason geometrically. Additionally, this method of instruction and learning Geometry places a greater emphasis on memorization skills than on the ability to think critically and rationally. It also makes the teacher the center of attention in the classroom and reduces pupils to passive listeners (Mereku, 2010). The way teachers teach is crucial because it influences how interested learners are in the content. In support of this, Emaikwu (2012) noted that the teaching approach has an impact on students' responses and decides whether they are motivated, interested, and involved in a class in a way that leads to learning.

However, studies show that students struggle to comprehend the principles and variations in executing 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 numerous potential causes for this, one of which is the traditional talk-and-chalk teacher-centered method of instruction, which does not make an exception to the premise that students are passive consumers of knowledge (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. In order to close the instructional and knowledge gap that is ostensibly caused by the teacher aspect, the study set out to determine whether it is worthwhile to incorporate GeoGebra into the teaching and learning process (teaching aids). Additionally, among today's tech-savvy adolescents, the old talk-and-chalk teacher-centered style of instruction, which presumes that students are passive consumers of knowledge, has lost its luster (Chimuka, 2017). Therefore, it is believed that using information technology (IT), specifically GeoGebra, into the teaching and learning of secondary school mathematics can act as a platform for better managing curriculum changes and developments (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

The adoption of technology is influenced by how it is viewed, how individuals create and share knowledge, the time period, and how supportive the environment is. As a result, Rogers' Diffusion Innovation Model (DIM) served as the study's main theoretical framework. Diffusion is the process through which an innovation is disseminated over time among individuals within social systems through a particular route (Rogers, 1995). DIM is the theory, in order to understand why, and how quickly new ideas and technologies spread across civilizations. It outlines the four key factors that affect how quickly a fresh concept spreads. Innovation, communication channels, time, and social system are some of these components. In the view of Rogers (2003), "An innovation is an idea, practice, or project that is perceived as new by an individual or other unit of adoption". Even if an innovation has been around for a while, for certain people it may still seem novel because of how they interpret it. Moreover, according to 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 indicates that interpersonal communication is more effective and that individuals' strong attitudes can be easily formed or altered. It is argued that one of the strengths of diffusion research can be seen when the time component is included (Rogers, 2003). Time is a factor that must be taken into account while measuring the innovation-diffusion process, adopter categorization, and adoption rate. The social system was defined by Rogers (2003) as "a set of interrelated units engaged in joint problem solving to accomplish a common goal" (p. 23). Innovations diffuse within the social system; as a result, the social structure of the social system influences this process.

Any new product's market success or failure is determined by the diffusion process. The theory highlights the role that people's attitudes play in their ability to adopt new technology. According to Roger's idea, the dissemination of innovations is a process that takes time to complete.

Technology in teaching and learning of mathematics

Virtually all mathematics syllabi make it abundantly obvious that a mathematics course is intended to help students develop attitudes and knowledge that will be useful to them in their future lives. As evidenced by the mathematics textbooks used in primary and secondary education, this is accomplished by placing a strong emphasis on the subject's practical applications and approaches to teaching and learning (Mwingirwa, 2012). Teachers should place a priority on helping students comprehend mathematical ideas and should offer a quality learning environment. Students must actively engage with the concepts or objects they are exploring, whether they are abstract or concrete, in order for learning to occur (Liang & Sedig, 2010). However, research has shown that when teachers use technology effectively in the classroom, student motivation and accomplishment levels rise (Engel & Green, 2011).

ICT integration is thought to offer innovative potential for assisting students' learning and promoting the acquisition of mathematical knowledge and abilities (Hohenwarter & Hohenwarter, 2009). Similar to this, it is thought that using technology in the classroom nowadays has a favorable impact on students' achievement and attitudes toward mathematics instruction (Ramadan & Hüseyin, 2014). The effective application of technology enhances the teaching and learning of mathematics in a classroom (Dick & Hollebrands, 2011). According to the results of several studies, the effective application of technological tools can help students develop advanced mathematical abilities including problem-solving, justification, and reasoning while also learning mathematical procedures and skills (e.g., Gadanidis & Geiger, 2010; Nelson, Christopher, & Mims, 2009; Pierce & Stacey, 2010; Roschelle, et al., 2010; Suh & Moyer, 2007). The integration of ICT is a key agenda item for the government of Ghana to increase standards in schools and encourage teachers' and students' access, skills, and knowledge of new technologies due to the technology's demonstrated usefulness in teaching and learning across the globe. They contend that technology may be utilized to remodel and reconstruct the classroom to create a setting that fosters the growth of higher-order thinking abilities (Kurt, 2010).

Effect of GeoGebra on Mathematics learning

GeoGebra is an open-source, community-supported mathematics learning environment that combines a number of dynamic representations, a number of mathematical subfields, and a wide range of modeling and simulation-related computing tools. Dikovi (2009) asserts that GeoGebra is more user-friendly than a graph calculator. A user-friendly interface, multilingual menus, commands, and support are all provided by GeoGebra. Additionally, it

supports math projects, diverse presentations, and guided and exploratory learning. Tens of thousands of people from all around the world, including math teachers and educators, are drawn to GeoGebra thanks to its user-friendly interface and web accessibility.

In order to determine the efficiency of utilizing GeoGebra software on students' learning of mathematics in Malaysia, Nazihatulhasanah and Nurbiha (2014) did a study on "The effects of GeoGebra on students' achievement." They came to the conclusion that GeoGebra is far more efficient than conventional teaching methods in the classroom when it comes to teaching mathematics. The researchers concur that increasing the usage of GeoGebra in mathematics instruction is essential for efficient instruction and long-lasting learning that enhances performance. In a related study by Royati, Ahmad, and Rohani (2010) titled "The Effects Of Geogebra On Mathematics Achievement: Enlightening Coordinate Geometry Learning," the authors looked at how using the free software GeoGebra affected students with high visual-spatial ability (HV) and low visual-spatial ability students' learning of coordinate geometry (LV). The results demonstrated that using computer-assisted instruction in conjunction with traditional classroom training enhances student performance and is more efficient than using traditional instruction alone. This amply exhibits GeoGebra's superior instructional efficacy over that of conventional construction tools.

METHODOLOGY

Research Design

For this study, a mixed method approach using both qualitative and quantitative research approaches was applied. According to Teddlie and Tashakkori (2009), mixed method research yields better conclusions and reduces the bias that results from the use of a single approach. Sequential explanatory mixed methods were employed. In a sequential explanatory design, quantitative data are initially gathered, and then qualitative data are gathered to further explain or expound on the quantitative results (Plano Clark, 2011). Because it avoids the use of metaphysical ideas that have generated unending discussion and controversy and also presents a very practical and applied research philosophy, mixed method is the finest paradigm for research (Bryman, 2012, Teddlie and Tashakkari, 2009, Regmi, 2010).

Population and Sampling

Students at the New Juaben Senior High School in the Koforidua municipal made up the study's population. Two thousand five hundred and twenty-three (2 523) students are enrolled

at the institution. Two levels of sampling were used in this investigation. The Form 2 classes was initially chosen using purposive sampling technique. Students in Form 2 were chosen because they were anticipated to have mastered some prerequisites in Geometry from the Form 1 mathematics curriculum. The two science classes in form 2, with a population of 119 students, were chosen using a purposeful sampling method. Then, 45 students were chosen for the study using simple random sampling. Interviews were conducted with six student volunteers. 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

Test items and interviews were used in this study. To determine the learners' level of knowledge, the pre-test exam for the sampled students was conducted. To determine whether there was a statistically significant difference in the performance of the same set of students before and after using GeoGebra, a post-test was conducted after they had been exposed to rigid motion with the help of GeoGebra. In order to answer the second research question, interviews were also conducted with a small group of chosen students after the post-test to discover their opinions on GeoGebra's role in teaching transformation in geometry.

Three ICT and math specialists from the University of Education in Winneba, Ghana, validated the instruments. Using the Crombach Alpha reliability technique, a trial test was done to determine the internal consistency of the instruments. Reliability coefficients of 0.76 was derived indicating 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).

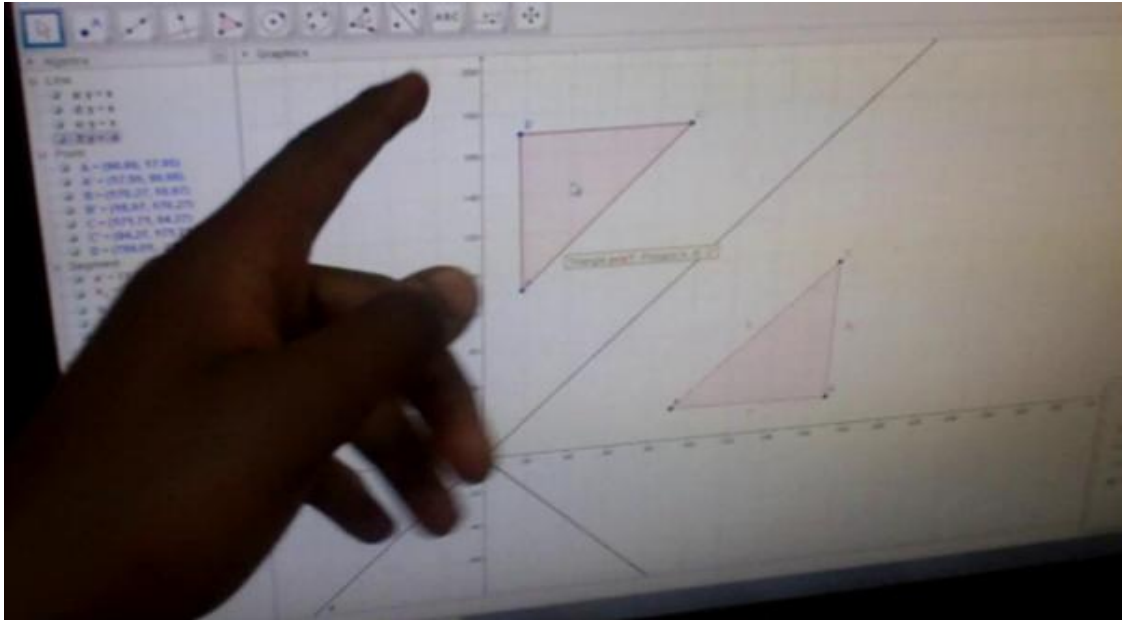


Figure 1: Simple basic reflection on GeoGebra along the line $x=y$ form classroom activities

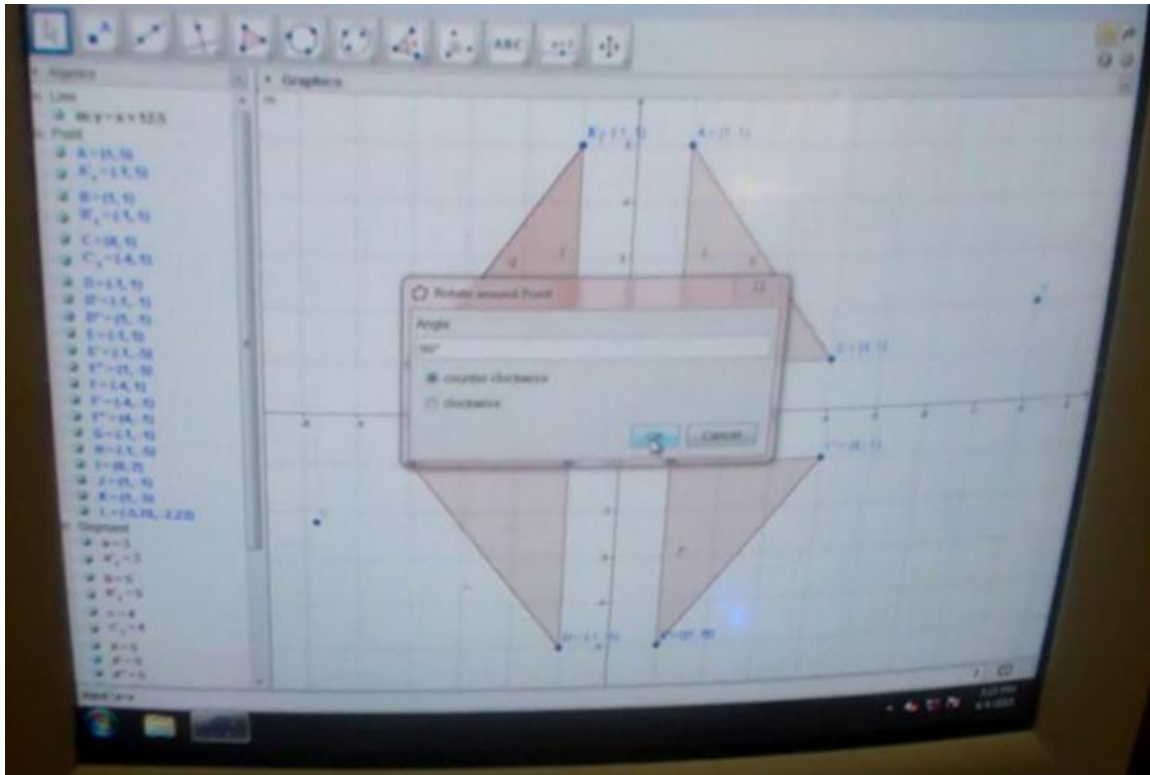


Figure 2: A rotation of a figure with the origin as the center of rotation at an angle of 90° from classroom activities

RESULTS AND DATA ANALYSIS

Both quantitative and qualitative data were generated by the study, indicating the results of the pre-test and post-tests for the students, inferential statistics were used to analyze the students' achievement test results. The Statistical Package for Social Sciences (SPSS) version 20 software was specifically used to do the t-test. The participants' pre-test and post-test scores were compared using the t-test to determine whether there was a statistically significant difference. The analysis of the scores was done using descriptive statistics (percentages, mean, and standard deviation). To respond to the second research question, the transcription and analyses of the student interview responses were undertaken.

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 1 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. In comparison to their pre-test scores, the students' average scores increased after being introduced to GeoGebra. Based on the study, using the GeoGebra app throughout the learning process led to an improvement in the students' learning achievement in transformation under geometry. This is consistent with research by Engel and Green (2011), MacBride and Luehmann (2008), and Shirley et al. (2011) that found student enthusiasm and achievement levels rose when teachers used technology effectively in the learning process.

Sketches produced using GeoGebra are precise and well-organized. Students had access to immediate exploring options with GeoGebra. As a result, this accelerated and enhanced the learning process (Ljajko and Ibro, 2013). When learning with GeoGebra, students spend less time constructing diagrams (sketches) and performing computations, giving them more opportunity to investigate the properties of various geometrical shapes. All of these elements played a role in the participants' exceptional performance on the post-test.

Additionally, the results of the open-ended interview show that incorporating GeoGebra into teaching and learning raises students' overall accomplishment levels and inspires 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. Numerous studies have demonstrated the positive motivational effects of GeoGebra on geometry students (BECTA, 2013; Dikovic, 2009; Zengin et al., 2010), including increased participation in class activities, improved attention in class, enjoyment of learning activities, self-confidence in learning, and recommendations of this teaching and learning approach.

This shows that learning, understanding, thinking, mental visualization, noticing details, internalization, and recall can all be facilitated and encouraged by utilizing GeoGebra. In this regard, Dikovic (2009) emphasized that GeoGebra can give students numerous opportunities to visualize the mathematical procedure and develop an intuitive worldview. Notably, their opinions align with those of high school students who participated in the study by Zengin et al. (2010) using GeoGebra-developed activities and apps. The high school students reported that they use GeoGebra willingly and enthusiastically. The program enhances visualization and offers a discovery-based learning environment, enabling them to recognize the connections between mathematical concepts. The information they previously memorized can be retained more easily when using GeoGebra.

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 established that GeoGebra was successful in establishing a link between mathematics concepts and the mental images that the users held. 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.

Once more, this paper's findings demonstrates that technology has a favorable impact on students' learning expectations and outcomes. To clarify, technological integration has the following advantages: Students will be more motivated and confident, students will be more engaged and collaborative, students will have more opportunities for hands-on learning, and students will have better technology abilities/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 instructors to be up to date with contemporary teaching techniques and keep pace with the changing times.
- It is also important for Mathematics teachers to align the teaching styles to the learning needs of the students for effective and consistent delivery of lessons.

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