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Geogebra Application for Trigonometry Subject: A Quasi-Experimental Research

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A R T I C L E I N F O

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A B S T R A C T

This study aimed to investigate Geogebra representation as a strategy in improving students' achievement in Trigonometry. This research employed an experimental design. The participants of this study were college students from Davao De Oro State College T-test was used to determine if there is a significant difference in the pre-test, post-test and gain scores in trigonometric functions of control and experimental groups. Results showed that there is a significant difference in the post-test and gain scores of the control and experimental groups. This means that students who were taught Trigonometric functions using Geogebra performed better than students who were taught using the traditional approach. This only shows that Geogebra is an effective strategy in teaching Trigonometry subject.

INTRODUCTION

Complexities in learning led to the undeniable fact that many learners still have difficulty defining and classifying trigonometry, even though it is an established component of the school mathematics curriculum. Trigonometry is used in countless ways, everything from blueprints of buildings and infrastructures to the electronic devices like mobile phones, laptops, and computers we are using daily. Wherever you see four sides, trigonometry is involved. Given the difficulties experienced by students in defining and classifying the geometrical concepts, there is a need to establish a great alternative to this challenge. The situation of poor student achievement calls for a need to improve the quality of education in the field of mathematics to avoid deterioration (Alcantara et al., 2017).

As a component of the trigonometry subject, defining and classifying trigonometry is considered a complex subject by many learners. This stems from the difficulties encountered while analyzing the properties of various trigonometry and distinguishing between their analyses (Mammarella et al., 2017).

Subsequently, students in the Philippines demonstrated lower performance in mathematics involving Trigonometry compared to the other 34 high-fulfilling countries around the world. Villaver (2014) indicated that the Philippines also ranked fifth to the last in the list of nations, the Trends in Mathematics and Science Study (TIMSS 2019). Moreover, the numeracy level of Filipino students is low (UNESCO, 2012), particularly in embracing abstract concepts related to Trigonometry and Algebra, which reflects poor students' mathematical skills, among others (National Research and Development Centre for Adult Literacy Numeracy, 2005). This global scenario of low performance in mathematics is also actual in the local setting. It was reported that Davao City Cluster V's overall Mathematics Proficiency Sessions (MPS) in Mathematics NAT result of Public secondary schools was 50.65 percent, which is far below the MPS of 75 percent that was set as the goal based on the memorandum guideline from the National Education Testing and Research Center, Department of Education (2012).

Since Mathematics is in almost every aspect of society, this has become a significant concern (Reyes, 2010). DeMarinis (2011) revealed that students could learn best if exposed to interactive trigonometry tools and technologies. Chemists use solid trigonometry to describe molecules, set designers in theaters use trigonometry to determine the best lighting for a play, and governments, international corporations, and individual investors use geometrical rules and trigonometry to determine production and employment, and prices. It is essential to use geometric concepts to explore how various mathematical concepts exist in students' minds. Ruiz (2012) expressed that proficiency in trigonometry is one of the education plans of DepEd due to the increasing demand for trigonometry-skilled workers recently. Alcantara and Basca (2017) added that this alarming situation of poor student achievement calls for an urgent need to improve the quality of education in the field of mathematics to avoid deterioration. The secondary-school mathematics curriculum is facing multiple challenges.

On this aspect, the researcher is interested in understanding Dynamic Mathematics Software, specifically the GeoGebra, and how it influences the mathematics achievement of high school students. It is believed that the widespread use of computers and digital technology is not only changing peoples' lives but has also significantly changed the experience of learning and teaching in mathematics (Wang et al., 2015). As such, the researcher will conduct a study applying the GeoGebra application to provide learners a dynamic learning environment in mathematics about trigonometry.

In light, most of the studies accessed by the researcher regarding the use of GeoGebra were either quantitative or qualitative designs. They mostly were in primary level and an international setting. In this study, the researcher used a quasi-experimental approach to better understand as an interactive tool in teaching trigonometry among students of Davao de Oro.

The use of technology has significantly increased. These developments have led to specific innovations and reforms in the field of education. These innovations and reforms encourage teachers and students to use technology in teaching and learning (Kim et al., 2019). This study would contribute to such efforts that focus on increasing the quality and number of resources for students, teachers, and curriculum developers and providing them with empirical evidence. It also serves as an example regarding investigations in other mathematics topics and leads the way to further research on students.

This leads to the sought of the researcher, which is to determine and discover GeoGebra Application as a strategy for Mathematics achievement in Trigonometry. This is the first time researching trigonometry using GeoGebra in the institution, conceptualizing using a new research locale specifically in CVSC-Maragusan to contribute significantly to knowledge. The mere fact that the researcher conducted this study in the institution is enough for it to be of great significance. The very fact that the researcher has researched to discover and assess the effectiveness of teaching strategy (GeoGebra) towards the Mathematics achievement of the learners of CVSC-Maragusan, which is new and contributes to the body of knowledge. Thus, the variables in this research paper are not yet studied by the other researchers in Davao City. This paper will answer the need of the problem.

Worldview and Theoretical Lens

The study is anchored on Bruner's Multiple Representations Theory (BMRT). Jerome Bruner, a prominent psychologist, proposed several theories in the field of education. Bruner's theories focused on cognitive psychology, developmental psychology, and educational psychology (Shore, 1997). Bruner's approach to learning was based on two modes of human thought: logic-scientific and narrative. For these modes of thought to be effective, Bruner emphasized that learners would better understand abstract concepts if a differentiated learning strategy were planned and implemented according to the learner's strengths (Bruner, 1985).

Bruner's theory (1966), which emphasized differentiation through representations, stated three stages of each mode of thought: enactive, iconic, and symbolic. The enactive stage focused on physical actions: Learning happens through movement or actions. Playing with a solid object and exploring its properties is an example of the enactive stage. In a virtual environment like GeoGebra, this stage is interpreted as manipulating graphs using pointers (mouse) or hand-held computers. On the other hand, the iconic stage fostered developing mental processes through vivid visualizations: Learning happens through images and icons. Investigating the properties of a solid shape from the textbook images is an example of an iconic stage. This stage is interpreted as observing teacher or peer demonstration on graphs or tables in a virtual environment. Lastly, the symbolic stage was characterized by the storage metaphor where information was kept in codes or symbols: Learning happens through abstract symbols. Finding out a solid's surface area or volume using mathematical symbols is a symbolic stage. In a virtual environment, this stage is interpreted as working with symbolic equations.

Bruner's work on representations has been interpreted as Multiple Representations (MR) theory in mathematics education. Many believed that MR theory would explain how students learn abstract mathematical concepts through various mathematical representations (Cobb, 1992). That view was agreed upon by several other reformist mathematics educators (Brenner, 1997) along with some influential mathematics education organizations (National Council of Teachers of Mathematics [NCTM]). Some prominent researchers advocated for MR theory to support students' cognitive processes in authentic, real-life problems and learning environments (Schonfeld, 1985).

Another supporting theory for this study is the Multiple Intelligences Theory by Gardner. This theory suggests that traditional psychometric views of intelligence are too limited. This theory suggested that all people have different kinds of intelligence. Gardner (1983) proposed that there are 8 bits of intelligence and has suggested the possible addition of ninth known as existentialist intelligence (Cherry, 2019)

THEORETICAL REVIEW

This section presents readings from the related literature, different books, journals, and articles of different authors relevant to the present research work. The researcher focuses on the understanding and discovering GeoGebra Application as a strategy for Mathematics achievement in Trigonometry.

Teaching Strategy

Policymakers have been encouraging teachers to integrate technology into mathematics classrooms. The Scientific and Technological Research Council of Turkey indicated that teachers at all levels needed to utilize new technologies in their teaching. Related to this point of view, the new curricula document emphasized the smart use of technology in education. In addition, The Ministry of National Education (2013) encouraged mathematics teachers to teach students the skills required to actively use information and communication technologies (ICT) in mathematics.

In accordance with the ideas proposed by influential policy-making organizations, some research in the context supported the use of technology in mathematics education. In another study, Baki and Güveli (2008) indicated that teachers could increase student success by creating well-prepared, technologically-rich learning environments. Bulut and Bulut (2011) found that mathematics teachers were open to adopting a variety of technologically rich teaching methods when they believed that these methods would assist students in understanding abstract concepts. Corlu (2015) showed that mathematics teachers teaching high-ability students at specialized schools were not more mentally prepared to implement technologies than teachers at non-selective general schools.

Conventional with GeoGebra Application in Instruction

GeoGebra, which offers dynamically connected multiple illustrations of mathematical objects through its graphical, algebraic, and spreadsheet views, also allows students to investigate the behaviors of the parameters of a function through its CAS component (Lavicza, 2009). The software is constantly being improved by a dynamic team of researchers and teachers. The software has an extensive collection of activities that are developed and donated by users all over the world. In recent years, the software is being translated into many languages, making it available in 45 different languages as of 2015.

Some researchers have explored the impact of GeoGebra on the achievement of objectives in different mathematical topics. Tarmizi (2010) used a traditional-experimental post-test only design to identify the differences in the average for high visual-spatial ability and low visual-spatial ability students after using GeoGebra for learning coordinate trigonometry. In their study, the sample consisted of 53 students who were 16 or 17 years old from a school in Malaysia. They reported three main findings: (a) students in the experimental group scored statistically significantly higher on the average than the students in the control group regardless of being HV or LV; (b) in the HV group, there was no statistically significant difference on the average between experimental and control groups in favor of the experimental group; (c) in the LV group, students in the experimental group scored statistically significantly higher on the average than the students in the control group. This research was noteworthy because it showed that GeoGebra might be an effective tool for students.

Another research study reflecting the positive impact of GeoGebra was conducted by Kllogjeri (2011) in Albania. The researchers presented some examples of how GeoGebra was used to teach the concepts of derivatives. In the study, they demonstrated three important theorems by using GeoGebra applets to explain: (a) the first derivative test and the theorem; (b) the extreme value theorem; and (c) the mean value theorem. The researchers used the direct teaching method and measured GeoGebra's impact on students' conceptual understanding. They concluded that the multiple representation opportunities and the dynamic features of GeoGebra helped students' understand the mathematical concepts faster and at a deeper level.

Mehanovic (2011) wrote about GeoGebra, which included two separate studies focusing on teaching integral calculus. The first study was conducted with two classes from two different secondary school students in Sweden. The researcher observed students through regular classroom visits. After several classroom observations, individual interviews with students were conducted. For the second study, the researcher asked the participating teachers to introduce the concept of integration and record their introductory presentations. The study's objective was to investigate teachers' introductions to the subject of integrals in a normal classroom environment. After the preliminary analysis of the teacher presentations, individual interviews were conducted with the participating teachers. As a result of the first study, it was found that the students had some concerns, such as using GeoGebra was time-consuming.

Furthermore, students seemed to believe that using GeoGebra was more confusing than their previous learning methods. In the second study, teachers reported some epistemological, technical, and didactical barriers to effectively using GeoGebra in the classroom. However, it was concluded in both studies that integrating a didactical environment with GeoGebra was complex, and teachers needed to realize the potential challenges.

Some GeoGebra impact studies were conducted in Turkey, as well. For example, Bilgici (2011) focused on the initial impact and the degree of knowledge retention for polygons. The study was conducted with 32 seventh-grade students. Following a pre-test, the experimental group was instructed using GeoGebra, and a constructivist face-to-face teaching was provided to the control group that did not have computer access. In the experimental group, one computer was given to two students to create a collaborative environment, enabling students to examine the prepared activities directly. Following an 11-hour long course, an identical post-test was applied. Students in the experimental group scored higher averages on the post-test than the students in the control group. When the test was administered for the third time a month after the intervention ended, the students in the experimental group performed better in terms of the amount of knowledge they retained.

Similarly, Zengin (2011) conducted a study with 51 high-school students to investigate the effect of the GeoGebra software in teaching the subject of trigonometry and to examine students' attitudes toward mathematics. In this study, participants were divided into two equal groups, one experimental and one control. Both groups were given a pre-test. While teaching was focused on using the GeoGebra software in the experimental group, the control group was taught only with a constructivist approach. Both groups showed improvement in their achievement scores at the end of the study. However, the averages in the experimental group were statistically significantly higher when compared with those in the control group.

Conventional Method

Conventional teaching or traditional teaching refers to a method involving instructors and the students interacting face-to-face in the classroom. These instructors initiate discussions in the classroom and focus exclusively on knowing content in textbooks and notes. Students receive the information passively and reiterate the information memorized in the exams (Azul, 2013). Technology in education is not new in today's classrooms, but many education systems are still limited by conventional teaching and learning methods (Poret, 2011).

Many teachers are still teaching their students in the same manner as to how they were taught and how their teachers were taught, not much progress in terms of the teaching perspectives. Transformation to less conventional teaching methods results is in fear and reluctance from teachers, who find the change challenging and risky (Weart, 2011). Lizada (2011) noted that many lecturers are still using conventional teaching. In conventional teaching classrooms, while the lecturer is explaining and writing on the board, students will copy the same thing onto their notes, daydreaming, and some sleeping. It would be difficult to stop students from copying the notes from the board and at the same time ensured that every student was paying attention in the class because the lecturer was too busy explaining the lecture. Conventional teaching is also limiting the room for more creative thinking and also seldom considering individual differences. It is necessary to realize these limitations in conventional teaching and take a step to move forward.

Information and Communication Technology is playing an active role now in education where it can promote learning through the interactivity feature that exists in it. Technology serves as the mediator to form interactive learning with students' participation (Opit, 2012). In Malaysia, the Ministry of Education had implemented the smart school project with the name of Malaysian Smart School Flagship since 1999. In this initiative, it is believed that the teaching and learning process can be reinvented, and the students are well prepared in this current information age. The traditional classroom teaching is transformed into a different setting where Information and Communication Technology (ICT) and multimedia technologies are involved. The role of the teacher is changed from purely providing information to a facilitator where students are encouraged to explore for more information and justify the correctness of the information (Multimedia Super Corridor Malaysia [MSC Malaysia]. Another reason for having such a project in Malaysia is that students are growing up in technology. Using the Internet to search for information is not strange to them anymore. Students like to see lecturers develop the teaching materials in presentation software such as Microsoft PowerPoint. The multimedia elements (graphics, animation, sound, video, and text) can attract the students' attention. The use of technology in the classroom has not increased much on the learner-centered practices. It is also noted that when traditional education involves technology, it does not mean that education will automatically take place. Educational institutions need to understand students' learning needs and not focus on technology alone (Ehat, 2009). Therefore, technology is to be treated as part of the learning process but not the process itself.

Trigonometry Achievement

The GeoGebra application has been considered by many as one of the most effective technological tools to foster conceptual understanding in mathematics education. Several researchers supported this view, claiming that such software would help students benefit from multiple representations of mathematical topics (Kutluca, 2012).

Another evidence in favor of this was based on research that investigated the impact of GeoGebra application for developing mathematical skills exclusively at the school level.

In an empirical study by Bakar, Tarmizi, Ayub, and Yunus (2009), however, no statistically significant difference was reported for either conceptual understanding or procedural knowledge in quadratic functions between a control group taught with a traditional approach and a treatment group taught with the software, in terms of student performance after an intervention with GeoGebra application. Researchers believed that their intervention, which was limited to six hours of instruction including the time spent to learn basic features of the DGS in the experimental group, needed to be longer for an impact to be observed.

Karakus (2008) investigated student achievement in transformation trigonometry when GeoGebra was used as the medium of instruction. The researcher conducted the study with 90 seventh-grade students in a school. The research design included a pre-test and a post-test. Karakuş divided the students into four groups according to their pre-test scores (high-success experimental and control groups; low-success experimental and control groups). After the intervention, there was a statistically significant difference between the high-success experimental and the control groups, in favor of the group of students who were taught with DGS, while there was not a statistically significant difference between the low-success experimental and the control groups. This research was noteworthy because it showed that GeoGebra might be an effective tool for high-success students with a large impact of 1.31 standard deviations.

Ipek and İspir (2011) believed that the application was essential both for students and teachers because such software brings about an environment that enables discourse and exploration. The researchers examined pre-service elementary mathematics teachers' algebraic proof processes and attitudes towards using DGS while making algebraic proofs. They designed a ten-week long course. The participants solved problems about algebra and proved some elementary theorems. The participants also wrote their reflections. At the end of the course, researchers interviewed a selected number of participants about their experiences with the software. They found some pre-service elementary mathematics teachers believed that this was valuable for learning and teaching mathematics. Moreover, these informants reported a positive change in their feelings for using technology.

In their study, Bulut (2011) showed that the application allowed teachers to observe and experience multiple teaching strategies. The purpose of their research was to investigate pre-service mathematics teachers' opinions about using Geogebra. They followed a qualitative research methodology with some forty-seven students at their sophomore year who reported a willingness to use the application when they would become teachers.

Geogebra Application and Mathematics Achievement

In this rapidly changing environment, education should change as quickly as the technology does. According to Fluck (2010), the future of Information, Communication and Technology (ICT) should play as a transformation role in education rather than integration into existing subject areas. The transformative view of ICT in education requires us to examine what new ways of pedagogies and curriculum are appropriate for a new generation working with new tools. In Malaysia, major investment in ICT has been implemented to achieve effective teaching and learning in the classroom. Malaysian Ministry of Education (MOE) has seen the application and the use of ICT in education as the key efforts to create knowledge-based workers which later will generate the economy.

By integrating ICT into their everyday teaching practice, teachers can provide creative opportunities for supporting students' learning and fostering the acquisition of mathematical knowledge and skills (Hohenwarter, 2009). When technological tools are available, students can focus on decision making, reflection, reasoning, and problem solving. Students can also benefit in different ways from technology integration into everyday teaching and learning. For example, Hohenwater (2009) claimed that the visualization and exploration of mathematical objects and concepts in multimedia environments can foster understanding in new ways.

With this, the OSS GeoGebra was selected from the available software packages for mathematics teaching and learning. GeoGebra is free open-source dynamic software for mathematics teaching and learning that offers trigonometry and algebra features in a fully connected software environment. It was designed to combine features of dynamic trigonometry in a single, integrated, and easy to-use system for teaching and learning mathematics (Ong, 2012). This dynamic mathematics software program was created by Markus Hohenwater and now has been translated to 40 languages.

Research on the effectiveness of integrating GeoGebra in teaching and learning mathematics still limited. However, research on other dynamic trigonometry softwares can offer effective impact in mathematics education and has the potential to promote student-centered learning and active learning (Jarvis. 2009). Furthermore it can enhance students' ability in visualizing the mathematical elements hence improving learning (Yunus, 2010).

Synthesis

This paper will see the effects on teaching and learning mathematics on the students enrich as they worked individually and in small groups to develop and present lessons with GeoGebra. This is also one of the guide on how Geogebra can be used as a vehicle for building links between a research-focused institutions and secondary school teachers.

In the teaching and learning of trigonometry, it has been often realized that students still lack the cognitive and process abilities in the total understanding of shapes and how to solve it. Although the teacher delivers the required knowledge to assist students in understanding the concepts of trigonometry, students seem to face a challenge in applying this knowledge to a given task. It is as though something more is required to guide students so that they are able to manipulate circle properties to truly understand and visualize the properties of trigonometry. This perception is supported by research (Battista, 1999; Prescott, Mitchelmore & White, 2002) whereby students faced challenges in studying trigonometry and many struggle to grasp the concepts and required knowledge. GeoGebra might play the role in filling up the gap by assisting students to visualize and understand circles through exploration. A review of literature also shows that using GeoGebra has an impact on students' understanding of trigonometry. Dogan (2010) revealed that GeoGebra had positively affected students' learning and achievement and improved their motivation. Another study by Erhan and Andreasen (2013) also suggested that students improved their mathematics understanding after using the dynamic trigonometry software. Students were able to explore and form conjectures and therefore had better scores as well. A study done in Malaysia to evaluate the impact of GeoGebra in learning transformations by Bakar, Ayub, Luan and Tarzimi (2002) revealed that secondary school students achieved better results using the software.

METHODOLOGY

This part presents the methods and procedures used in the conduct of the study. These included the research design, research locale, and research respondents.

Research Design

The study employed a quasi-experimental design to assess GeoGebra as a strategy for teaching Trigonometry. The quantitative research is used to quantify the problem by generating numerical data that can be transformed into usable statistics. It is used to quantify attitudes, opinions, behaviors, and other defined variables and to generalize results from a larger sample population.

Place of the Study

The research was conducted in Davao De Oro State College, Maragusan, Davao De Oro, Philippines.

Participants

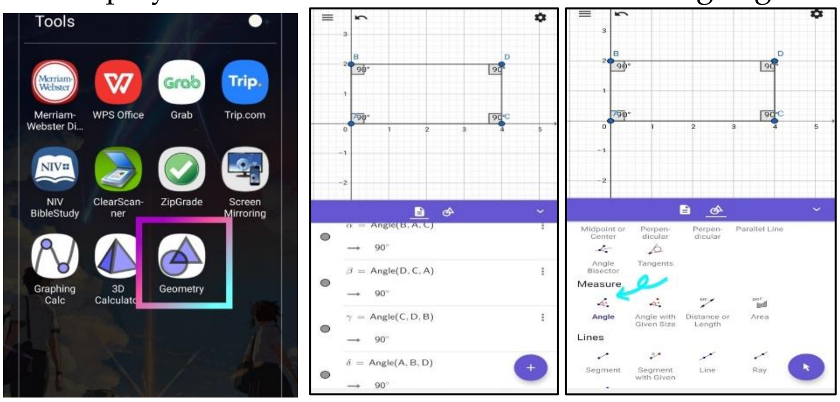
The participants of this study were college students from two fixed groups or sections in Davao De Oro State College in Maragusan Branch. The researcher applied traditional and conventional way of teaching with the integration of Geogebra approach in the experimental group while the control group was taught using the traditional or conventional approach.

Data Analysis

The data gathered from the respondents were evaluated and analyzed using frequency counts, percentage distribution, mean, standard deviation and t-test.

Before the implementation of GeoGebra application, the respondents were made to understand that they hold the right to know the procedures of the research as well as the benefits and risks if there are any. They still reserve the right to discontinue their participation at any time and under valid grounds. The two groups which are the experimental and the control group. Series of discussion and implementation of the application to the experimental group, right after discussion, the assessment applied.

In conventional method integrating GeoGebra application, manipulative pictures were first used before proceeding to the abstract teaching. Students were asked to install the free offline mobile application and given the instructions from their activities, they used the app in learning quadrilaterals. A classical teaching method was conducted to the other group in which, the researcher employed a lecture and discussion in teaching trigonometry.



RESULT

This chapter presents the tabulated data, findings of the study, analysis and interpretation of the data obtained from the respondents.

Table 1
Mean Scores in Trigonometry Functions of the
Learners in the Control andExperimental Groups

	Pre – test			Post – test			Gain		
	Mean	SD	Description	Mean	SD	Description	Mean	SD	Description
Control Group	5.67	2.14	Low	9.3	1.58	High	3.63	1.92	Very Low
Experimental Group	6.33	2.04	High	12.8	2.14	High	6.47	3.00	Low

Table 1 presents the mean pre-test scores, mean post-test scores, and mean gain scores in Trigonometric Functions of the learners in the control and experimental groups. In the pre-test, the control group gained a mean score of 5.67 and the experimental group obtained a mean score of 6.33. In the post-test, the experimental group got a higher mean score of 12.8 while the mean score of the control group was 1.58. Moreover, the total gain score of the experimental group was 6.47 while the control group had a total gain score of 3.63. With these results, the control group which was taught using the conventional method gained lower scores in pre- test and post-test as compared to experimental group which utilized Geogebra representation.

Table 1 reflects the mean pre-test scores, mean post-test scores, and mean gain scores in quadrilaterals of the learners in the control and experimental groups. Based from the results, the control group which experienced the conventional method in teaching gained lower scores in pre-test and post-test compared to experimental group which utilized GeoGebra application and representation. This implies that the discussions in the classroom and methods that focus exclusively on knowing content in textbooks and notes are not fully effective as a strategy in teaching mathematics in a specific area. Students receive the information passively and reiterate the information memorized in the exams (Azul, 2013). Technology in education is not something new in today's classrooms, but many education systems are still limited by conventional teaching and learning methods (Poret, 2011). Furthermore, the experimental group which was demystified to be the strategy of a GeoGebra application provided higher scores in pre-test and post-test. This leads to the idea that GeoGebra application is observed to be effective in teaching.

This result confirms what Kutluca (2012) said that the GeoGebra application has been considered by many as one of the most effective technological tools to foster conceptual understanding in mathematics education. Several researchers supported this view, claiming that such software would help students benefit from multiple representations of mathematical topics. The research of Kutluca (2012) encouraged instructors to use the software in their teaching because of its capacity to foster understanding of multiple topics of advanced mathematics at both school and university levels, including different geometries, such as the Euclidean, linear space, and projective geometries, complex tracing and algebra, such as matrices, functions, limits, and continuity. Kultuca advocated that student who used this could explore multiple perspectives in a single construction.

Another evidence in favor of this was based on research of Adante (2012) that investigated the impact of GeoGebra application for developing mathematical skills exclusively at the school level.

Table 2
Test of significant difference in the pre-test scores in Trigonometric Functions of control andexperimental groups

	Mean	t	p-value	Remarks
Control Group	5.67			

Experimental Group	6.33	1.36	0.18	Not Significant

T-test was used to determine if there is a significant difference in the pre-test scores in trigonometric functions of the control and experimental groups. The overall p-value of 0.18 shows that there exists no significant difference in the pre-test scores of both groups. This implies that the two sections or groups are homogenous.

Table 2 shows the test of significant difference of the pre-test scores of both control and experimental groups. The p-value of 0.18 indicates a no significant difference in the pre-test scores obtained by the learners in both groups. This result implies that prior to the conduct of the experiment, the learners in both groups are of the same level in terms of their knowledge about quadrilaterals.

Bakar, Tarmizi, Ayub, and Yunus (2009) who affirmed that there is no statistically significant difference that was reported for either conceptual understanding or procedural knowledge in quadratic functions between a control group taught with a traditional approach and a treatment group taught with the software, in terms of student performance after an intervention with GeoGebra application. Researchers Bakar, Tarmizi, Ayub, and Yunus (2009) believed that their intervention, which was limited to six hours of instruction including the time spent to learn basic features of the DGS in the experimental group, needed to be longer for an impact to be observed.

Table 3
Test of significant difference in the post-test scores and mean gain scores of controlled andexperimental groups

	Mean	T	p-value	Remarks
Post – Test				
Control Group	9.3	7.24	.000	Significant
Experimental Group	12.8			
Gain				
Control Group	3.63	4.84	.000	Significant
Experimental Group	6.47			

Table 3 shows the test of significant difference in the post-test scores and mean gain scores of the control and experimental groups. The overall p-value of .000 revealed that there is a significant difference in the post-test and mean gain scores of the control and experimental groups. This means that students who were taught Trigonometric functions using GeoGebra performed better than students who were taught using the traditional approach. This only shows that Geogebra is an effective strategy in teaching Trigonometry subject.

Table 3 shows that the test of significant difference in the post-test scores and mean gain scores of control and experimental groups is significant. The overall p-value of 0.000 expresses its significant difference. This result is parallel to the result of the study conducted by Ipek and İspir (2011) who concluded that after the intervention and they found that there was a statistically significant difference between the high-success experimental and the control groups, in favor of the group of students who were taught with Dynamic Geometry System (DGS). This research was noteworthy because it showed that GeoGebra might be an effective tool for high-success students

In their study, Bulut (2011) showed that the application allowed teachers to observe and experience multiple teaching strategies. The purpose of their research was to investigate pre-service mathematics teachers' opinions about using GeoGebra. They followed a qualitative research methodology with some forty-seven students at their sophomore year who reported a willingness to use the application when they would become teachers.

Some researchers have explored the impact of GeoGebra on achievement of objectives in different mathematical topics. Tarmizi (2010) used a quasi-experimental post-test only design to identify the differences on the average for high visual-spatial ability and low visual-spatial ability students after using GeoGebra for learning coordinate geometry. In their study, the sample consisted of 53 students who were 16 or 17 years old from a school in Malaysia. The researchers divided the sample into two homogeneous groups, where the experimental group students were taught with GeoGebra and the control group students were taught with traditional methods. Each group was categorized into two types of visual-spatial ability (high [HV] and low [LV]) by applying a paper and pencil test covering 29 items. They reported three main findings: (a) students in the experimental group scored statistically significantly higher on the average than the students in the control group regardless of being HV or LV; (b) in the HV group, there was no statistically significant difference on the average between experimental and control groups in favor of the experimental group; (c) in the LV group, students in the experimental group scored statistically significantly higher on the average than the students in the control group. This research was noteworthy because it showed that GeoGebra might be an effective tool for students.

Synthesis

The results support the notion that the use of technology has become part of everyday life; thus, allowing students to use technology in the classroom can benefit their education (Bloemsm, 2013). As mentioned by the CCSS.MP5 (2017) students should use technology as a tool for expanding their understanding of mathematical concepts. There has been research conducted on what technology is best for integrating into mathematics (Bloemsma, 2013). There are several studies that focus on student engagement with mathematics and found students to be more interactive when using the technology (Haydon et al., 2012; Perry & Steck, 2015). Technology has also shown to have a positive effect when integrated into game-base instruction, manly for practice application or used in geometric activities (Haydon et al., Kutluca, 2013; 2012; Perry & Steck, 2015). Therefore, technology such as iPads have become popular tool when teaching since they have several application that can be used in education (Perry & Steck, 2015).

These results evidently give a support on Bruner's work on representations which has been interpreted as Multiple Representations (MR) theory in mathematics education. Many believed that MR theory would offer an explanation how students learn abstract mathematical concepts through a variety of mathematical representations and that view was agreed upon by several other reformist mathematics educators along with some influential mathematics education organizations (National Council of Teachers of Mathematics [NCTM]). Some prominent researchers advocated for MR theory due its ability to support students' cognitive processes in authentic, real-life problems and learning environments (Bruner, 1985).

With these findings, Bruner's Multiple Representations Theory (BMRT) has been integrated which is focused on cognitive psychology, developmental psychology, and educational psychology. Bruner's approach to learning was based on two modes of human thought: logic-scientific and narrative. In order for these modes of thought to be effective, Bruner emphasized the notion that learners would have a better understanding of abstract concepts if a differentiated learning strategy was planned and implemented according to the learner's individual strengths (Bruner, 1985).

Furthermore, Bruner's theory (1966), which emphasized differentiation through representations, stated that there are three stages of each mode of thought: enactive, iconic, and symbolic. The enactive stage focused on physical actions: Learning happens through movement or actions. Playing with a solid object and exploring its properties is an example of the enactive stage. In a virtual environment like GeoGebra, this stage is interpreted as manipulating the graphs by using pointers (mouse) or hand-held computers. On the other hand, the iconic stage fostered developing mental processes through vivid visualizations. Learning happens through images and icons. Investigating the properties of a solid shape from the text book images is an example of iconic stage. In a virtual environment, this stage is interpreted as observing teacher or peer demonstration on graphs or tables. Lastly, the symbolic stage was characterized by the storage metaphor where information was kept in the form of codes or symbols: Learning happens through abstract symbols. Finding out a solid's surface area or volume by using mathematical symbols is an example of symbolic stage. In a virtual environment, this stage is interpreted as working with the symbolic equations.

Moreover, Bruner's work on representations has been interpreted as Multiple Representations (MR) theory in mathematics education. Many believed that MR theory would offer an explanation how students learn abstract mathematical concepts through a variety of mathematical representations and that view was agreed upon by several other reformist mathematics educators along with some influential mathematics education organizations (National Council of Teachers of Mathematics [NCTM]). Some prominent researchers advocated for MR theory due its ability to support students' cognitive processes in authentic, real-life problems and learning environments (Bruner, 1985).

CONCLUSION

The control group gained a mean score of 5.67 and in experimental group, it provided a mean score of 6.33 in pre-test. On the other hand, in post-test category, experimental group took the higher mean score of 12.8 than the mean score of the control group which was 9.3. Moreover, the total gain score gave the experimental group a 6.47 while the control group gained a 3.63. With these, as compared to experimental group which utilized GeoGebra application and representation, the conventional method in teaching gained lower scores in pre-test plus post-test.

There was no significant difference exists in the pre-test scores in quadrilaterals of control and experimental groups of the GeoGebra approach.

In terms of the post-test scores and mean gain scores of control and experimental groups, it showed significant difference.

RECOMMENDATION

The teachers may assess and may give students the intended application and activities which would lead them to improve their academic achievement in Mathematics.

The learners have to focus on improving their abilities in solving simple calculations in Mathematics with the guidance of teachers and on their scaffolding techniques. Further, they have to elevate their ways of grasping knowledge and ideas by being active and class and being a resourceful learner.

The institution may build programs and more activities and tasks that could help learners to become more spontaneous and responsible in managing math difficulties and challenges. In addition, teachers and parents have to be the best support system in handling these matters on achievement and coping challenges.

The faculty/researcher may create trigonometry modules using different approaches.

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