

Effectiveness of Using Geogebra on Students' Understanding in Learning Circles

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ABSTRACT

The use of technology in the pedagogical process is growing at a phenomenal rate due to the vast availability of gadgets. As a result, educationists see the urgent need for integrating technology in students' mathematical activities. Therefore, the purpose of this quasi experimental study was to investigate students' understanding in learning circles using GeoGebra. Fifty-three Year 9 (Form 3) students from two intact classes participated in this study with one class assigned as the experimental group and the other as the control. Findings of this study showed a significant difference existed in the mean scores between these two groups. The result indicated that students in the experimental group outperformed those in the control group. In addition, a survey instrument was used to elicit students' perception on the use of GeoGebra. Analysis of the questionnaire responses indicated a positive overall perception of using GeoGebra in learning about circles.

Keywords: *GeoGebra, circles, understanding, effectiveness, mathematics*

INTRODUCTION

Teaching and learning with the use of technology has many advantages such as providing greater learning opportunities for students (Roberts, 2012); enhancing student engagement (White, 2012) and encouraging discovery learning (Bennet, 1999). In the teaching and learning of Mathematics, especially geometry, it is important for students to be able to imagine, construct and understand construction of shapes in order to connect them with related facts. Therefore, a computer will assist students in imagining and making observations (Dogan, 2010). A number of technology tools are available such as interactive whiteboards, calculators, Geometers Sketchpad and GeoGebra. This paper will discuss in detail the use of GeoGebra software to conduct learning of circles in mathematics.

Statement of Problem

In the teaching and learning of geometry, it has been often realized that students still lack the cognitive and process abilities in the total understanding of circles. Although the teacher delivers the required knowledge to assist students in understanding the concepts of circles, 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 circles. This perception is supported by research (Battista, 1999; Prescott, Mitchelmore & White, 2002) whereby students faced challenges in studying geometry 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 geometry. 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 geometry 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.

Objectives and Research Questions

The main objective of this study was to investigate the effectiveness of using GeoGebra on students' understanding of circles. Further, the study also aimed at investigating if this learning method surpassed the traditional method and if students perceived learning using technology as useful. The secondary objective was to elicit students' perception in learning circles using GeoGebra.

This study aimed at addressing the following research questions:

1. What is the effectiveness of using GeoGebra on students' understanding of circles as compared to the traditional approach?
2. What were student perceptions about Geogebra in the learning of circles?

Significance of Study

Findings from the study served to inform teachers about students' learning processes, particularly those related to using the GeGebra software in relation to mathematics. The findings reveal the processes involved as well as the challenges and issues teachers will need to consider when using GeoGebra software.

The results outline how the different interactions with technology, peers and teachers affect learning. Consistent with the Vygotskian perspective, the role of social interaction in the learning process (Vygotsky, 1978) may become more evident. In other words, how learners interact with their peers and knowledgeable adults to advance their mental functions serve to inform educators about the use of GeoGebra software.

In addition, the study provides information on how learners of different abilities interact to perform assigned tasks. Such information is crucial in planning lessons for large classes and where learners are of varied abilities. The study reveals how technology integration facilitates the teaching and learning of circles; in particular, the findings help to redefine the role of the teacher so that concepts such as "facilitator" and "guide at the side" may become more apparent.

GeoGebra Software

GeoGebra was designed by Markus Hohenwarter as an open-source dynamic mathematics software that incorporates geometry, algebra and calculus into a single, open-source, user-friendly package (Hohenwarter, Jarvis, & Lavicza, 2008). This software combined features of older software programs such as Maple, Derive, Cabri and Geometer's Sketchpad (Sahaa, Ayub, & Tarmizi, 2010). GeoGebra is a free and user-friendly software that connects geometry and algebra (White, 2012). GeoGebra's support materials are rather impressive (especially for a free program), where it provides wide-ranging online help feature, 42-page help manual in pdf format, downloadable tutorials, and a variety of detailed lessons using video-based step-by-step examples. These materials are very concise, easily accessible, and professionally done, with supplementary suggestions contributed by users. This concerted assisted environment is described as focusing on "quality versus quantity" in the GeoGebra website (Grandgenett, 2007).

Theoretical Framework

Therefore with regard to the Zone of Proximal Development (ZPD), in the learning of circles, the more skilled students will be able to assist their peers with information and manner of constructing diagrams and the more capable students will be able to fill in gaps in their peers' knowledge or explanations they have missed. The peers then gain a different insight and develop a different manner of understanding circle concepts. In addition, when working in groups due to the differing ZPD of each student, they may have differing views; therefore through interaction with peers they can achieve shared understanding. However, in such a situation, there must be a balance in terms of the insights and ideas contributed by each group member; it is important to have shared views and justifications of opinions to reach mutual understanding. This enables all students to participate in critical thinking skills because one's cognitive development becomes apparent when new views and ideas are taken into the current cognitive state.

In conclusion, a constructivist classroom may contain the following four characteristics: cognitive exploration to encourage inquiry and direct hands-on, minds-on activities; student autonomy where students are in charge of their own learning; social interaction where students work together in groups with opportunities for cognitive conflict; and student-centered where students' ideas and opinions are important. In this respect, it can also be concluded that the teacher's role here is more of a facilitator.

The study draws upon the constructivist theory of social interaction for cognitive development. The main principles will anchor on the zone of proximal development (ZPD) and scaffolding. Students generally have challenges

in understanding mathematical concepts; therefore in this study the GeoGebra software was introduced as a scaffold to enhance student understanding of circles.

The ZPD is described as the variance between one's mental age and the level one might attain in problem solving with guidance. Scaffolding refers to the guidance provided for one to reach the ZPD. In this study the GeoGebra software basically acts as the primary scaffold in assisting and guiding the students to reach their ZPD. The students were required to work in pairs to construct diagrams and make observations based on their constructions. Students formed their own interpretations through shared understanding with the guidance of the GeoGebra where they were able to explore and visualize on their own. On top of that, the teacher and peers also played a part in the scaffolding process.

The teacher advocated instructional intervention at the beginning of the lesson to introduce the software tools to enable the students to work in pairs on their own using the step-by-step guide without the teacher's assistance. The teacher's role hereafter will be more of a facilitator, to encourage students to actively participate in the lesson and make significant connections. This relates to Piaget's work, where he stressed the need to provide formal instructions to assist students to reach a developmental stage where they are able to accommodate and assimilate information at a given level of complexity.

Social interaction between peers gave the students opportunities to guide one another and reach a level of shared understanding. Here the higher ability students play a big role in helping the lower ability students to reach their ZPD. The higher ability students also benefit through the new ideas and views of their peers.

Students were also placed in groups of two to work on constructing the diagrams. They had to work hand-in-hand assisting each other in constructing diagrams and making conjectures based on their findings. Vygotsky's views are closely related to this learning environment where he emphasized that social interaction and cultural environment contribute to cognitive development. However, this must take place within the zone of the individual's potential development. In this study, students were placed in groups where the scaffolding process can take place for them to construct circles based on what they already know and with help accepted from their peers when needed. In this environment the teacher acts as a facilitator. This manner of learning enhances critical thinking skills as students contribute ideas and views to reach a common understanding. However, this process had to be closely monitored to ensure a balance in terms of input from both group members. Here the higher ability students played a bigger role in helping the lower ability students reach their ZPD. The higher ability students also benefit through the insights gained from their peers. GeoGebra gave the students an opportunity for peer interaction to enhance understanding and visualization of the concept of circles. The conceptual framework called T2S4VU is represented in Figure 1.

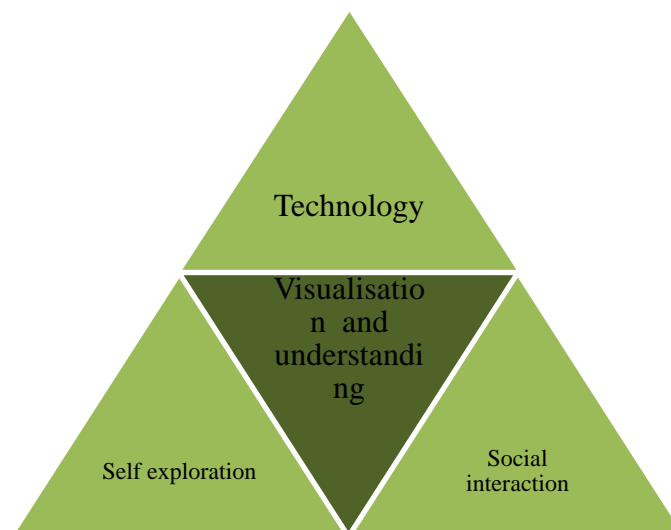


Figure 1. The T2S4VU Conceptual Framework.

The T2S4VU conceptual framework is explained in the following part:

T= Technology. Technology, in this respect the GeoGebra software is an important scaffold to bridge the ZPD.

S= Self-exploration. This is a central concept in constructivism to enable students to project their actual learning level.

S= Social Interaction. This allows the learners to interact and learn from peers and knowledgeable others to reach their potential learning level

As such the 2Ss' are related to the concept of ZPD.

V = Visualization. This is an important process in the learning of circles

U = Understanding. Understanding is a crucial thinking skill to grasp any mathematical concept

Review of Literature

Technology integration in the teaching and learning process in the classroom has attracted a lot of attention in recent years. Providing a rich learning environment to promote social interaction, critical thinking skills and a holistic understanding of their learning experiences has brought about the urgency to incorporate technology in the classroom. Classroom teaching should be engaging and intellectually stimulating to inspire students in learning Mathematics. Therefore, the learning process designed using technology will be able to cater for such an environment. Similarly, the National Council of Teachers of Mathematics (NCTM, 2000) in the document "Principles and Standards for School Mathematics" listed technology as one of the key principles to enhance the quality of mathematics, suggesting that, "Teachers should use technology to enhance their students' learning opportunities by selecting or creating mathematical tasks that take advantage of what technology can do efficiently and well – graphing, visualizing and computing." (NCTM 2000, p. 10). In the fast moving era of technology, it is essential to keep up with the current interventions and innovations in relation to technology to meet its relevance for the present and future (Abd. Rafie, 2002; Hatfield & Bitter, 1994; Idris, 2006; Pomerantz, 1997).

Based on a study, Myers (1993) developed a learning environment that included a hypermedia database about Mesoamerica. It was an observational study of middle school students using the system within a framework of problem-based learning for mastering content and thinking skills. The study reported that embedded problem-solving strategies facilitated higher order thinking only when coupled with teacher support. In a doctoral study evaluating a model technology program for developing critical thinking abilities of junior high school students, Jacks (1996) reported an improvement of critical thinking skills over a 3-year period. To evaluate the study, qualitative data in the form of survey questionnaires, in-depth interviews, observations and examination of documents and reports were conducted. This was supported by quantitative data collected from two tests of critical thinking, namely the Cornell Critical Thinking Test, Level X (Ennis, Millman & Tomko, 1985) and the Ennis-Weir Critical Thinking Essay Test (Ennis & Weir, 1985).

Dogan (2010) conducted an experimental design study using a pre-post test to evaluate the success of students learning using the GeoGebra software. It was a twelve hour course held for a period of two weeks involving two eighth grade classes. It was observed that computer based activities can efficiently be used in the learning process and the GeoGebra software encouraged higher order thinking skills. The software was also observed as having a positive effect in motivating students toward learning and retaining their knowledge for a longer period. This was proven based on a recall test conducted a month later. In another study, Kemp (2006) found that high ability Grade 9 boys felt the lesson was interesting. Students explored their learning beyond what was assigned by the teacher and were happy and engaged in the lesson using GeoGebra software. The teacher was able to identify students who faced challenges in such a setting and did not engage in the lesson; therefore it was suggested that further strategies need to be incorporated to motivate most students.

Herceg and Herceg (2010) conducted a study on two groups of students. One group used applets only, whilst the other used the GeoGebra software and applets. The study tested how to incorporate computer-based learning to reduce the working process of numerical integration. The results of this study showed that the GeoGebra experimental group gained more knowledge and skills than the control. This study also suggested that GeoGebra use is helpful for students who face difficulty in solving mathematical problems since they do not have to spend so much time solving by hand. According to Erhan (2013) dynamic software improves students' understanding of mathematics; students were able to explore and form conjectures and therefore had better overall scores.

Bakar, Ayub, Luan and Tarzimi (2002) compared GeoGebra to a software program created by them on two groups of Malaysian secondary school students and found that students using the GeoGebra software to study the transformation topic achieved better results than students using the created software.

Leong (2013) conducted a study to determine the effects of using the dynamic software, Geometer's Sketchpad (GSP) in the teaching and learning of graph functions. This study was conducted among Form Six students in a Malaysian secondary school. A quasi-experimental design using intact sampling was employed. A significant difference was observed in the achievement of the experimental group as compared to the control. This indicates that the dynamic software (GSP) had a positive effect on student achievement and attitude towards learning graphs of functions.

METHODOLOGY

Research Design and Sample

This study employed a quasi-experimental design. A pre test and post test was administered to both the groups. The experimental group underwent an intervention where they learnt mathematics using GeoGebra for one week while the control group, on the other hand, learnt mathematics using traditional learning method not involving GeoGebra. Participants for this study were Year 9 (Form 3) students selected from an International school in Selangor. Two intact classes consisting of 53 students in total were selected for this study from a population of 133 students. One class was assigned as an experimental group while the other became the control group. The experimental group consisted of 28 students while the control group consisted of 25 students. The researcher taught both the groups.

Table 1. Composition of samples

No of students	Group of students	Breakdown of No (n)	Percentage (%)
53	Experimental	28	53
	Control	25	47
Total		53	

This study used two instruments. The first instrument was the achievement test that functions to gauge the students' understanding of circles while the second instrument was a survey questionnaire to elicit the students' perceptions in using the GeoGebra software.

At the beginning of the study both the experimental and control group took a pre test to gauge their abilities on the concept of circles. The pre test and post test contain similar items. Both the tests consist of 21 questions, 8 multiple choice questions and 13 problem solving questions. At the end of the treatment, a post test and a set of survey questionnaires were administered to elicit the students' perceptions in using the GeoGebra software.

Data Analysis

Achievement test scores were analyzed using inferential statistics. Specifically, the *t*-test was executed using the Statistical Package for Social Sciences Version 18.0 (SPSS 18.0) software. The *t*-test was used to test for statistical significance difference between the control and experimental groups at the beginning of the study and at the end. This was done primarily by comparing the mean score of the pre test and post score of both the groups. Descriptive statistics were used to analyze the data from the survey questionnaire.

RESULTS

The results of this study are presented in the following sections according to the research questions:

(1) Effectiveness of using GeoGebra on students' understanding of circles

To determine whether any significant differences existed between the pre test mean score of both the control and experimental groups, an independent sample *t*-test was done.

Table 2. Results of the independent *t*-test on the pre test of both groups

Group	Mean	Post test		t-value	Sig (2 tailed)
		S. D.			
Experimental (n = 28)	6.96	2.15		-1.368	.177
Control (n = 25)	7.88	2.71			

t-value significant at $p < .05$

Table 2 shows that the control group obtained a mean score of 7.88 while the experimental group obtained a mean score of 6.96. The mean score difference between the groups was 0.92 with a *t*-value of -1.368. Nonetheless, the *p*-value was 0.177 ($p > .05$) indicating that the difference in the mean score of the two groups was not significant. This result illustrated that both the students in the control and experiment group were similar in abilities before the treatment was administered.

Table 3. Results of the independent *t*-test on the post test of both groups

Group	Mean	Post test		t-value	Sig (2 tailed)
		S. D.			
Experimental (n=28)	16.46	3.28		3.989	.000*
Control (n=25)	12.24	4.40			

t-value significant (*) at $p < .05$

To determine whether any significant differences exist between the post test mean score of both the control and experiment group, an independent sample *t*-test was carried out.

Table 3 shows that the control group obtained a mean score of 12.24 while the experimental group obtained a mean score of 16.46. The mean score difference between the groups was 4.22 with a *t*-value of 3.989. However, the *p*-value was low ($p < .05$) indicating that the difference in the mean score of the two groups was significant. This finding illustrated that the students in the experimental group performed better using GeoGebra than the control group using the traditional learning method. The students in the experimental group performed better in the post test compared to the control group.

Table 4. Results of the paired sample *t*-test

	Mean	S.D.	<i>t</i>	Sig. (2 tailed)
Pair 1 posttest score - pretestscore (Experimental)	9.50	2.89	4.91	.000
Pair 2 posttest score - pretest score (Control)	4.36	4.44	17.41	.000

t-value significant at $p < .05$

A paired samples *t*-test was conducted to compare the pre test and post test scores for the experimental and control groups. The result as illustrated in Table 3 shows that the mean score difference between the post test and pre test of the experimental group was 9.50 as compared to the control group with 4.36. For the experimental group, the

t -value obtained was 4.91 and the p -value obtained was low ($p < .05$) indicating the differences between the pre and post test score was significant. For the control group, the t -value obtained was 17.41 and the p -value obtained was low ($p < .05$) indicating the differences between the pre and post test score was significant. This indicated that there was a significant improvement in the scores of both the experimental and control groups. From these results, it can be seen that students gained from both approaches but the students in the experimental group appear to have a higher mean difference or improvement in scores compared to the control group.

(2) Students’ perception on GeoGebra in the learning of circles

Table 5. Student perceptions on use of GeoGebra in the learning of circles

		Y	N
1.	I was excited about using GeoGebra software	82% (23)	18% (5)
2.	I learnt a lot using GeoGebra	93% (26)	7% (2)
3.	I felt confident using the GeoGebra software during the activities	54% (15)	46% (13)
4.	I was very engaged in the learning process	82% (23)	18% (5)
5.	I benefited a lot through the teacher-students interaction	93% (26)	7% (2)
6.	I was able to visualize and answer the questions after each activity	82% (23)	18% (5)
7.	I was able to think creatively and critically in the discussions and during the question and answer session	75% (21)	25% (7)
8.	I was able to make logical assumptions when attempting to hypothesize	79% (22)	21% (6)
9.	I enjoyed learning mathematics much more using GeoGebra	75% (21)	25% (7)
10.	I was able to form better connections between previous learning and new learning	75% (21)	25% (7)

Results from Table 5 show that students generally gave positive feedback toward the GeoGebra software. The majority of students, about 93% of them mentioned that they learnt a lot using GeoGebra and benefited much through the teacher-students interactions when using GeoGebra, while 82% of the students mentioned that they were excited about using GeoGebra software, engaged in the learning process, and were able to visualize concepts related to circles and answer the questions after each activity. About 75% of students said that they were able to think creatively and critically in the discussions and during the question and answer session, were able to make logical assumptions when attempting to hypothesize. They also enjoyed learning mathematics much more when using GeoGebra and were able to form better connections between previous learning and new learning. However, some students reported they were not so confident when using the GeoGebra software.

Discussion

The GeoGebra software can be used as an enabler in the teaching and learning of Mathematics, and more specifically of circles, as there was a significant increase in experimental students’ conceptual understanding of circles as compared to the control group. The use of the GeoGebra software not only increased student scores, it was observed that the the software enabled realization of a vibrant classroom where cooperative and collaborative principles of learning were evident. This finding is supported by Bakar, Ayub, Luan and Tarzimi (2002) and Zengin, Furkan, and Kutluca (2012), where a study was conducted with two groups using the pre and post achievement test to learn mathematical concepts.

The above findings also corroborate other studies done to determine the effects of a technology-rich environment on students learning (Bennet, 1999; Dogan, 2010; Idris, 2006; Roberts, 2012; White, 2012). This improvement can be attributed to the design of the constructivist learning environment anchored on the twin concepts of scaffolds and zone of proximal development. Thus, it is equally important that the teacher as the main curator of

the learning environment be equally enlightened regarding the advantages of a technology-enabled classroom. Studies done by professional mathematics bodies should be constantly referred to when reviewing the impact of new learning technologies. The document "Principles and Standards for School Mathematics" listed technology as one of the key principles to enhance the quality of mathematics, suggesting, "Teachers should use technology to enhance their students' learning opportunities by selecting or creating mathematical tasks that take advantage of what technology can do efficiently and well – graphing, visualizing and computing" (NCTM, 2000, p. 21).

The findings also suggest that technology is a great motivational tool as students' confidence increased when both the GeoGebra and learning videos were used to enhance the students' learning process. This was especially beneficial for the lower ability students. Technology acted as a scaffold which enabled learners to reach their zone of proximal development (Vygotsky, 1978). This finding is supported Dogan's (2010) study whereby it was observed that computer based activities encouraged higher order thinking skills, and had a positive effect in motivating students toward learning.

When students were asked how the software affected them, they had many positive things to say, such as: it made them more engaged in the learning and enabled them to think at higher levels. In a similar study, Kemp (2006) found that high ability Year 9 boys felt the lesson was interesting, and students were able to explore their learning beyond what was assigned by the teacher and were happy and engaged in the lesson. Furthermore a study by Leong (2013) on Form Six students in a Malaysian secondary school discovered that using Geometer's Sketchpad software had positive effects on students' achievement and attitude toward mathematics.

On a lesser note, it was found that students reported they did not have high confidence in the use of GeoGebra software. This could have been attributed to insufficient time to familiarize themselves with the key strokes of the software.

CONCLUSION

In this study, the GeoGebra software has proven to be an effective tool in enhancing Mathematics teaching and learning, specifically in learning circles. Students were able to experience a hands-on method of learning which had a positive effect in enabling them to understand the concepts better rather than just being passive learners.

The software also gave the teacher and students the opportunity to work through the concepts together through exploration and visualization. This encouraged a more interactive teacher-student interactional environment where everyone worked as a team to guide, help and assist one another to reach the required goals. The **T2S4VU** conceptual framework (T= Technology whereby the GeoGebra software was an important scaffold to bridge the ZPD; S= Self-exploration which was a central concept in constructivism enabling students to project their actual learning level; S= Social Interaction to allow learners to interact and learn from peers and knowledgeable others to reach their potential learning level as specified in the ZPD. The cognitive aspect of learning circles was represented by V = Visualization and U = Understanding). Overall, GeoGebra is an effective tool in assisting the teacher and students in the mathematics classroom to achieve the principles of constructivist learning. This supports the findings of Akkaya, Tatar, and Kagizmanli (2011). Based on the findings of the current study, it is highly recommended that teachers be encouraged to use GeoGebra software in teaching Mathematics. This should be coupled with research to establish better findings to conclusively ascertain whether GeoGebra does actually have an effect on learning of broader mathematical concepts and on different levels of students.

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