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The Effects of GeoGebra on Mathematics Achievement: Enlightening Coordinate Geometry Learning

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Abstract

Many research indicated that ICT has been proven useful as a tool in supporting and transforming teaching and learning. In mathematics classroom, ICT can help students and teachers to perform calculation, analyse data, explore mathematical concepts thus increasing the understanding in mathematics. This quasi-experimental study with non-equivalent control group post-test only design was conducted to examine the effects of using a free-software called GeoGebra in the learning of Coordinate Geometry among students classified as high visual-spatial ability students (HV) and low visual-spatial ability students (LV). The Spatial Visualization Ability Test Instrument (SVATI) had been used to categorize the students in different spatial ability level. A total of 53 secondary school students in Wilayah Persekutuan Kuala Lumpur participated in the study. They were assigned into two different groups. One group was taught Coordinate Geometry using GeoGebra while the other underwent learning the traditional way. Students' mathematics achievement was measured using post test at the end of the intervention. The test format was based on Additional Mathematics KBSM syllabus. Independent samples t-test results showed that there was a significant difference in mean mathematical achievement between the GeoGebra group (M=65.23, SD=19.202) and the traditional teaching strategy group (M=54.7, SD=15.660); [t (51) = 2.259, p= .028 < .05]. This study also found that the HV students performed better than the LV students in both group. Findings showed that there were no significant different among HV students between GeoGebra group and traditional group. Meanwhile the LV students in GeoGebra group (M=64.07, SD=21.569) significantly outperformed the LV students in traditional group (M=48.79, SD=15.106); [t (51) = 2.222, p= .036 < .05]. These findings showed that the use of GeoGebra enhanced the students' performance in learning Coordinate Geometry.

***Keywords*:** Open Source Software; GeoGebra; Visual- spatial ability; Coordinate geometry

1. Introduction

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 in

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Malaysia as the key efforts to create knowledge-based workers which later will generate the economy (Ismail, 2008).

For that purpose, Government of Malaysia has launch several mega project which could embark the use of ICT during teaching and learning. Through the Multimedia Super Corridor mega projects, Smart School is built with the latest ICT equipment to make the Research and Development (R & D) in line with contemporary needs. The Smart School program is intended to produce minded workforce and technology literacy, democratization of education, encouraging the participation of stakeholders in education, developing the potential of the individual as a whole, and provide opportunities to enhance individual strengths and capabilities (Smart School Conceptual Blueprint, 1997). It also aims to optimize the potential of Malaysian students in all schools using ICT as an enabler to make instructional in the classroom more effective (Ministry of Education Malaysia, 2006). Besides Smart School Program, several other initiatives has also been implemented by the government to enhance the use of ICT in Teaching and Learning. This project involves providing computer lab and also broadband infrastructure to schools, SchoolNet project, EduWeb TV, the Teaching and Learning Science and Mathematics in English (PPSMI) and other various ICT initiatives.

This effort by the Malaysian MOE are also in line with The National Council of Teachers of Mathematics' (NCTM) *Principles and Standards for School Mathematics* where they dedicated technology as one of their six principles for school mathematics. According to NCTM (2000), technology is essential in teaching and learning mathematics where it can influences the mathematics that is taught and enhances students' learning. Besides that, technology can also help students to furnish their visual images of mathematical ideas, organizing and analyzing data, and can compute efficiently and accurately. Technology can support students to investigate in every area of mathematics, such as geometry, statistics, algebra, measurement and number (NCTM, 2000).

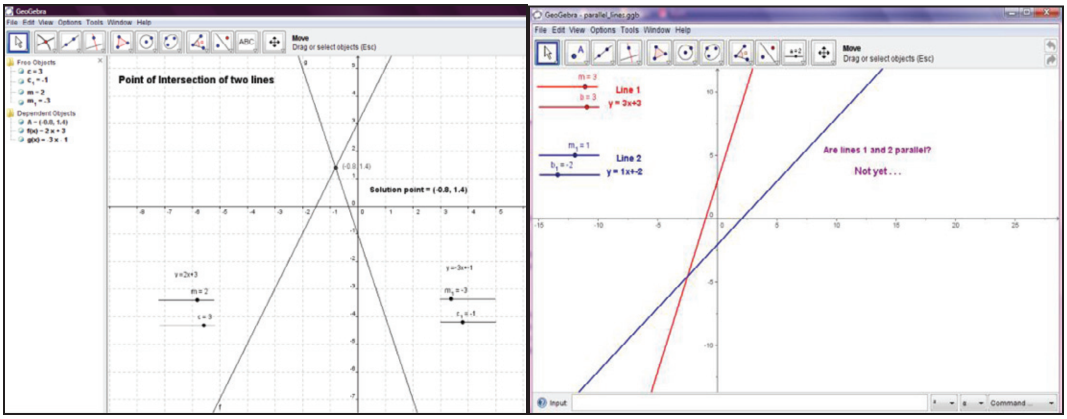
Literatures had shown that the advancement of computer has brought great innovation and thus school teachers need to be competent in using computers so that they would maximize its use in teaching and learning (Kumar, Rose, & D'Silva, 2008). In addition, Nik Azis (2008) distinguished that the use of ICT has to be integrated in Mathematics Curriculum in both formal and informal ways and not just make it as an extra component. 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 & 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, Hollebrands (2007) highlighted that new learning opportunities are provided in technological environments which potentially help students to engage with different mathematical objects and level of understanding. ICT also adds a new dimension to the teaching and learning of Mathematics by helping students to visualize certain mathematics concept (Voorst, 1999). Van Voorst (1999) and Hohenwater (2009) claimed that the visualization and exploration of mathematical objects and concepts in multimedia environments can foster understanding in new ways.

In Malaysia, geometry is taught in primary and secondary school levels. Coordinate Geometry is taught in form four for students who take the Additional Mathematics subject. Geometry was defined as a basic skill by the National Council of Teachers of Mathematics (NCTM, 2000). Learning geometry may not be easy and a large number of students fail to develop an adequate understanding of geometry concepts, geometry reasoning and geometry problem-solving skills (Battisa, 1999; Idris, 2006). According to Noraini Idris (2006) the lack of understanding in learning geometry often causes discouragement among the students, which invariably will lead to poor performance in geometry. She claimed that some factors have been identified causing the difficulties in geometry learning, those are geometry language, visualization abilities and ineffective instruction. Furthermore, she highlighted that spatial visualization has been linked with geometric achievement because geometry is visual in nature. Geometry requires visualizing abilities but many students cannot visualize three-dimensional objects in a two-dimensional perspective. Geometry is the study of shape and space (Guven & Kosa, 2008). Without spatial ability, students cannot fully appreciate the natural world. A number of studies have demonstrated that technology has an important potential to develop spatial skills. Travis and Lenon (1997) used MAPLE, a computer software package with graphing capabilities to enhance spatial skills found that students in the experimental class scored better on the spatial skills test. In another research, Hodanbosi (2001) used Geometer's Sketchpad (GSP), a dynamic geometry software found that students in the GSP group had higher significant achievement scores on the Geometry Achievement Test rather than students in traditional group.

They are various types of commercial softwares available for teaching and learning Mathematics in the open market. For example Geometer's Sketchpad, Derive, Cabri, Matlab, Autograph and others. These mathematical software have been used in school and also university worldwide. Teachers need to purchase those software in order to use it in the classroom which some of the software is really costly. However, there are softwares that could be freely used by educators in classroom teaching. The term Open Source Software (OSS) allows user to download any softwares that are available and suitable for the users. Until August 2010, there are more than 240,000 software projects that have been registered in SourceForge.net which is the world's largest open source software development site (SourceForge.net, 2010). Softwares which are similar to OSS and related to mathematics instructions such as SAGE, FreeMat, GeoNet, JLab, Maxima, Axiom, YACAS, JsMath and others are ready to be downloaded and used in teaching and learning

1.1 GeoGebra Software

In this study, 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 geometry and algebra features in a fully connected software environment. It was designed to combine features of dynamic geometry software (e.g. Cabri Geometry, Geometer's Sketchpad) and computer algebra systems (e.g. Derive, Maple) in a single, integrated, and easy to-use system for teaching and learning mathematics,(Hohenwarter, Jarvis, & Lavicza, 2009). This dynamic mathematics software program was created by Markus Hohenwater and now has been translated to 40 languages. Users all over the world can freely download this software from the official GeoGebra website at http://www.geogebra.org. Research on the effectiveness of integrating GeoGebra in teaching and learning mathematics still limited. However, research on other dynamic geometry softwares can offer effective impact in mathematics education and has the potential to promote student-centered learning and active learning. Furthermore it can enhance students' ability in visualizing the mathematical elements hence improving learning (Hodanbosi, 2001; July, 2001; Mohammad, 2004; Ahmad Tarmizi, Mohd Ayub, Bakar, Mohd Yunus, 2010). Figure 1 shows several snapshots taken by using GeoGebra software.



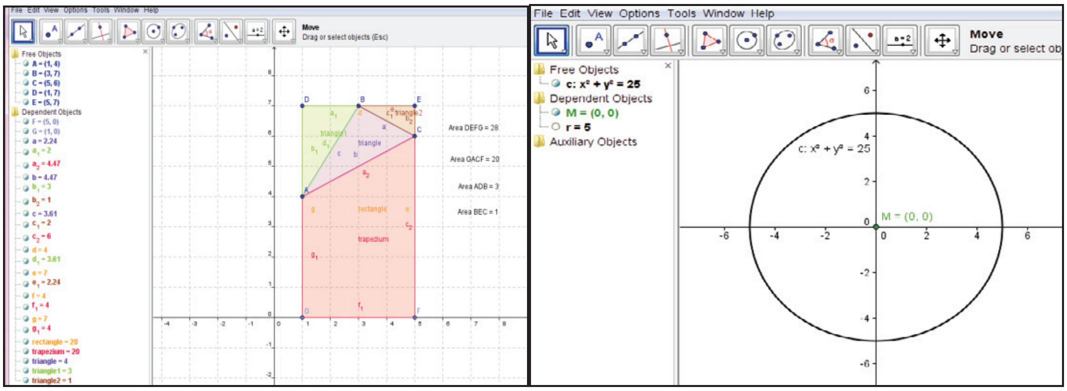


Figure 1 : GeoGebra software

2. Research Objectives

The objectives of this study are as the following:

1. To identify differences in the mean posttest scores between students utilizing GeoGebra and conventional instruction.
2. To identify differences in the mean posttest scores of students utilizing GeoGebra and conventional instruction among high visual-spatial ability (HV) students.
3. To identify differences in the mean posttest scores of students utilizing GeoGebra and conventional instruction among the low visual-spatial ability (LV) students.

3. Methodology

This research used the quasi-experimental study with non-equivalent control group post-test only 2 x 2 (visual-spatial ability x treatment) factorial designs. The research sample consisted of two homogeneous Form Four classes in Sekolah Menengah Perempuan Jalan Ipoh, Kuala Lumpur, aged 16 and 17 years. A total of 60 students involved in this study but only 53 of them managed to complete the tasks assigned. The total number of students in GeoGebra group was 27 students whilst the conventional group was 26 students. Each group was categorized into two types of visual-spatial ability (high-HV and low-LV). The spatial visualization ability among the participants was based on the result from the Spatial Visualization Ability Test Instrument (SVATI) which consisted of a paper and pencil test containing 29 items. Three types of spatial tasks were used in SVATI; Cube construction tasks, 3D spatial ability task and mental rotation tasks (Alias, 2000). The SVATI was administered two weeks before treatment. Table 1 shows the GeoGebra and conventional group based on their level of spatial visualization ability.

Table 1: Factorial Design 2 x 2

Visual-spatial Ability	Students' Group	
	GeoGebra Group (GG)	Control Group (CG)
High Visual-spatial	GGHV	CGHV
Low Visual-spatial	GGLV	CGLV

The instructional materials for this study consisted of a set of lesson plan on the topic of Coordinate Geometry for Form Four Additional Mathematics syllabus and a set of module prepared by the researcher. The module which consisted of the content of the lesson was distributed to the students to use as guide throughout the instructional process. On the first phase, the treatment group was introduced how to use GeoGebra software. The GeoGebra familiarisation modules were developed to enable the students to be familiar with the software. Students were required to explore the various features in the tool and its function. During the second phase, both group were introduced the basic concept of the Coordinate Geometry and mathematical problem solving session. Later on in the third phase, they underwent teaching and learning phase and were given assessment questions to evaluate the extent of short term learning. On the third phase, the treatment group was taught Coordinate Geometry integrated with GeoGebra whilst the control group followed teaching and learning session in the traditional teacher-centred approach. Seven modules were developed to enable the students learn about the Coordinate Geometry. It takes 40 minutes to complete each module. At the end of the treatment session during the fourth phase, students were given the post-test. The post-test consisted of six subjective questions and were carried out using paper and pencil for 45 minutes.

4. Findings

The findings of this study are discussed based on the objectives stated. Analyses of the post-test achievement scores were conducted using Statistics Package for Social Science (SPSS).

4.1 Differences in the mean posttest scores between students utilizing GeoGebra and conventional instruction

From the above table, the result of the independent-t test comparing the post-test results of the two groups showed that there was a significant difference between mean performance scores of the control group (M=54.7, SD= 15.660) compared to GeoGebra group (M= 65.23, SD= 19.202; t(51) = 2.259, p = .028 < .05). The difference between the means is 10.53 points on a 100-point test. The effect size (*eta squared,* η^2) is approximately 0.09, which is considered to be a moderate effect (Cohen, 1988). This finding indicated that students who had learned Coordinate Geometry using GeoGebra was significantly better in their achievement compared to students who underwent the traditional learning.

Table 2: Independent-t test comparing the result post-test between Control group and GeoGebra group

Group	N	Mean	Standard Deviation	t	DF	Significant
Control Group	26	54.7	15.660			
				2.259	51	0.028
GeoGebra Group	27	65.23	19.202			

DF : Degrees of Freedom

4.2 Differences in the mean posttest scores of students utilizing GeoGebra and conventional instruction among high visual-spatial ability (HV) students

Table Three shows results from the HV students. The result of the independent-t test comparing the post-test results of the two groups showed that there was no significant difference between mean performance scores of the control group (M=61.667, SD= 13.793) compared to GeoGebra group (M= 67.583, SD= 16.489; t(22) = 0.953, p = .351> .05). However, the mean score of the HV students in GeoGebra group is higher than the result of the HV students in Control Group. The effect size (*eta squared)* (η^2) is approximately 0.04, which is considered to be a very small effect (Cohen, 1988).

Table 3: Independent-t test comparing the result post-test between high spatial visualization ability students (HV) between Control group and GeoGebra group

Group	N	Mean	Standard Deviation	t	DF	Significant
Control Group	12	61.667	13.793	0.953	22	.351
GeoGebra Group	12	67.583	16.489			

DF : Degree of Freedom

4.3 Differences in the mean posttest scores of students utilizing GeoGebra and conventional instruction among the low visual-spatial ability (LV) students

The following table, depicts mean performances of the Geogebra and conventional groups of low visual-spatial ability (LV) students. The results of the independent-t test comparing the post-test results of the two groups showed that there was a significant difference between mean performance scores of the control group (M=48.786, SD= 15.106) compared to GeoGebra group (M= 64.067, SD= 21.569; $t(27) = 2.222$, $p = .036 < .05$). The difference between the means is 15.281 points on a 100-point test. The effect size (*eta squared,* η^2) is approximately 0.15, which is considered to be a very large effect (Cohen, 1988). This finding showed that LV students who had undergone learning Coordinate Geometry using GeoGebra was significantly better in their achievement rather than students underwent the traditional learning. It showed that the GeoGebra software enhanced the LV students in their mathematics performance.

Table 4: Independent-t test comparing the result post-test between low spatial visualization ability students (LV) between Control group and GeoGebra group

Group	N	Mean	Standard Deviation	t	DF	Significant
Control Group	14	48.786	15.106	2.222	27	.036
GeoGebra Group	15	64.067	21.569			

DF : Degree of Freedom

5. Conclusion

The results of the study indicated that there was a significant difference between the means of the students' scores on the posttest in favor of the GeoGebra group. The findings showed that computer assisted instruction as a supplement to traditional classroom instruction is more effective than traditional instruction alone. The findings of this study is consistent with the study by Hennessy, Fung and Scanlon (2001), Hannafin and Foshay (2008), Ahmad Fauzi et. al. (2010) and Ahmad Tarmizi et. al. (2010) which found positive impact of utilizing mathematical learning softwares thus enhancing students learning and understanding. It clearly demonstrates the instructional effectiveness of GeoGebra as compared to the traditional construction tools. This study gives an alternative to the teachers to utilize the OSS mathematics software as a tool in their instructional activities. Students can download this software and can use it from their home. Cost is usually the determining factor in acquiring new teaching and learning aids in school, so OSS can solve the problems whereby there are no cost required.

This finding shows the high on spatial visualization ability (HV) students in GeoGebra group have a better score compared to the control group but it was not significant. Nevertheless in combination of low on spatial visualization ability (LV) students, there was a significant difference between mean performance scores of the control group compared to GeoGebra group. LV students in GeoGebra group performed significantly better than control group. It showed that GeoGebra provides students in various visualization ability levels to learn geometric concepts and to explore relationships easily. The study conducted by Guzen and Kosa (2008) among the mathematics teachers also showed that computer supported activities contributed to development student mathematics teachers' spatial skills. GeoGebra as a Dynamic Geometry Software can be used as an effective tool in learning by way of visualization to promote learning and enhance understanding. Similarly with the utilizing of Geometer's Sketchpad as a visualization tool in learning mathematical concept found by Almeqdadi (2005) and Teoh and Fong (2005). Therefore, it can be recommended to mathematics teacher to use DGS GeoGebra in their instructional process in school. This software provide teachers and students with a free new tool, a new way of using technology with visual aids to help students to interact with the mathematical concepts individually or in groups, in the classroom, or at home, or at the most convenient place according to needs of the teachers and students using computers. This tool can be use as complementary activities to the regular classroom setting, where students can get immediate feedback of their findings, in the classrooms activities as well as in their homework.

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