Effect of utilizing Geometer's Sketchpad on performance and mathematical thinking of secondary mathematics learners: An initial exploration

Kamariah Abu Bakar, Rohani Ahmad Tarmizi,
Ahmad Fauzi Mohd. Ayub, Aida Suraya Md. Yunus

Abstract—Educational researchers globally have articulated high expectations for the utilization of computer in improving the teaching and learning of mathematics. The teaching and learning of geometry utilizing dynamic geometry softwares have been explicitly indicated in the Malaysian secondary school Mathematics syllabus. Teachers were recommended to utilize licensed dynamic geometry softwares such as the Geometer's Sketchpad (GSP) software. This study attempted to explore and compare the effects of integrating the GSP and the traditional teaching strategy in the teaching and learning process. Specifically, the effects on mathematical performance in secondary mathematics and students' attitudes towards the respective approaches used to teach the groups were investigated. The mean overall mathematical performance for the group using the GSP was 11.78 (SD = 4.10) while the mean overall performance for traditional teaching strategy group was 13.03 (SD = 3.65). Independent samples t-test results showed that there was no significant difference in mean mathematical performance between the GSP group and the traditional teaching strategy group, [t (90) = 1.552, p>0.05]. Findings also indicated that the use of GSP induced higher mathematical thinking process amongst the GSP group. These findings showed that the use of GSP had an impact on both mathematical thinking process and performance. However, these findings provided evidences of limited and deficient use of the technology, specifically in the teaching of mathematics at the Malaysian secondary level.

***Keywords*—**Geometer's Sketchpad, mathematical performance, mathematical thinking, mental load

Manuscript received November 8, 2008: Revised version received December 31, 2008. This work was supported in part by the Ministry of Science, Technology and Innovation (MOSTI), Malaysia.

Kamariah Abu Bakar is a Professor at the Faculty of Educational Studies, Universiti Putra Malaysia (UPM) and an associate researcher at the Institute of Mathematical Research (INSPEM). Universiti Putra Malaysia, 43400, Serdang, Selangor Darul Ehsan, Malaysia (phone: 603-8946-8196; fax: 603-8948-0119; e-mail: kamarab@ gmail.com).

Rohani Ahmad Tarmizi is an Associate Professor at the Faculty of Educational Studies, UPM. Currently she serves as the Head of the Laboratory of Innovations in Mathematics Education at the Institute of Mathematical Research (INSPEM), UPM. (e-mail: rohaniat@gmail.com).

Ahmad Fauzi Mohd Ayub is a senior lecturer at the Faculty of Educational Studies, UPM and also an associate researcher at the Institute of Mathematical Research (INSPEM). (e-mail: aieelah@gmail.com).

Aida Suraya Md Yunus is an Associate Professor at the Faculty of Educational Studies, UPM. She is an associate researcher at the Institute of Mathematical Research (INSPEM) and the National Higher Education Research Institute. (aida@educ.upm.edu.my)

I. INTRODUCTION

IN recent years, a lot of talks have been expressed on the use of Information, Communication and Technology (ICT) in education. Along with the implementation of IT in education, it provides us a good chance to make use of ICT in teaching and learning mathematics. In fact, educational researchers globally have articulated high expectations for the utilization of computer and other technology in improving the teaching and learning of mathematics [1][2]. The idea that technology is an essential tool for teaching and learning mathematics has also been supported by the National Council of Teachers of Mathematics [3]. Apart from having an influence on mathematical content, technology also influences the way teachers teach mathematics and how it enhances student learning. NCTM further recommends that technology be used wisely by well informed teachers to support mathematical understanding at all levels. The use of ICT could help teachers not only in the teaching of Mathematical concepts but also to lighten their workload and allow teachers to solve students' problem individually [4]. Computers may be used to teach, to facilitate studying of several topics, to help students to learn how to use technology, and to increase the effectiveness of performing academic tasks [5].

Currently, in the market there are various hardwares and softwares available for the purpose of teaching and learning of Mathematics, each of which differ in their functions, strengths and weaknesses. Some of these are in the form of hand held tools (e.g. calculators and graphic calculators) and softwares such as Mathcad, Derive, Mathematica, Matlab, Geometer's Sketchpad, Autograph dan Matlab. For the software application, it could perform like a mindtool to facilitate learning. Unlike a calculator that gives an answer when instructions are posed, a mindtool would form a learning partner [6] with a student and allowing the student to learn through exploratary. In this setting, a student would be able to interact with the environment [7]. A comparison of the use of Graphing Calculator, Autograph software and a Conventional strategy was conducted and the researchers found that each of these technology utilizations with their associated instructional efficiency may be useful for instructional researchers and educators in improving mathematical performance as well as in the utilization of technology in teaching and learning [8].

The learning of geometry emphasizes the mastery of deductive skills in writing proof. This is one of the ways, in fact an important way in past experiences, to learn geometry [9]. In the current trend of the teaching ang learning of mathematics, it is no longer adequate to teach students with the traditional expository approach at the current age of knowledge explosion.

In response to the foreseeable change of global knowledge economy, the teaching and learning of geometry utilizing dynamic geometry softwares have been explicitly indicated in the new Malaysian secondary school syllabus implemented in 2003 [10], and taught in English after 30 years being taught in the National Language (Bahasa Malaysia). In the syllabus, teachers have been recommended to utilize dynamic softwares and one such dynamic geometry software licensed to be used in the Malaysian schools is the Geometer's Sketchpad (GSP) software, developed partly under the Geometry Visual Project conducted in Pennsylvania and sponsored by the National Science Foundation.

Geometer's Sketchpad (GSP) is a software programme that revolutionized the teaching and studying of mathematics especially in geometry. It is a computer software system for creating, exploring, and analyzing a wide range of mathematics concepts in the field of algebra, geometry, trigonometry, calculus, and other areas [11]. It is a dynamic geometry construction and exploration tool, which can make an enormous difference in the students' learning of Mathematics. It is easy to use and encourages a process of discovery in which students first visualize and analyze a problem and then make conjectures before attempting a proof. It is versatile enough to be used from primary 6 onwards through undergraduates and the subject of mathematics that are relevant to be used with GSP are algebra, geometry, pre-calculus and calculus.

The GSP lets the user explore simple, as well as highly complex, theorems and relations in geometry [12] and has the ability to record students' constructions as scripts. The most useful aspect of scripting ones' constructions is that students can test whether their constructions work in general or whether they have discovered a special case (p.450). In addition, the GSP software provides the process of learning and teaching in a more creative way [13].

Numerous studies have been conducted to explore the effectiveness of the use of the GSP in mathematics learning, especially in the learning of geometry, since the GSP was discovered in the recent years. Lester [14] found that GSP increased students' achievement in geometry while [15] found significant change in attitude towards geometry among students. In another research, [16] found that positive correlations existed between levels of attitudes toward problem solving with perceived ease of use and perceived usefulness towards utilization of technology among GSP learners. Other research, such as [17], concluded that students who used the GSP (dynamic instructional environment) had higher significant achievement scores on a test containing the concepts of reflection and rotation. Growman [18] studied using GSP in a Geometry Course for Secondary Education Mathematics Majors and offered three examples of how sketchpad is used. The findings of the study showed that students wanted to get their own copies of GSP software. The use of GSP showed more positive reaction from both the students and the instructors in testing conjectures and constructions. In another study [19], on the pedagogical usability of GSP digital module conducted, it was found that students were more investigative in trying out their ideas and the use of GSP may produce generation who are not only ICT literate but also Mathematics literate. White and Norwich [20] presented nine exercises on using different technological tools – GSP was one of them – in explaining Calculus concepts. The GSP can be used in teaching some of Calculus concepts such as vertices of a triangle, midpoint, equation of a line, slope of a line and the trigonometric identities of sine, cosine and tangent functions.

Quinn [21] found that GSP is an invaluable aid in teaching graph theory in her discrete-in mathematics class. She found that GSP not only supplied a tool to create sketches that were tedious to draw and redraw or were hard to visualize, it also gave her students insight to prove or disprove certain graphs based on the theory. Norhayati's [22] study on 68 students in a post-test found that the achievement mean of the control group differ significantly from the GSP group. Her findings showed that students using GSP achieved higher than the control group. Another study [23] was conducted using a sample of 52 students from the Model School, Yarmouk University, Jordan, was to investigate the effect of using the GSP on students' understanding of some of the geometrical concepts. Data showed that there was a significant difference between the means of students on the post-test, and more gain in the scores from the pre-test to the post-test in the case of the experimental group. The students in the experimental group used the GSP software and the textbook once a week, while the students in the control group used only the textbook. This result showed that students using the GSP software performed significantly better than students who only learned by the traditional approach of using textbook only. Purdy [24] on the other hand used GSP to visualize maximum-volume problems. He found problems like the maximum-volume that was once reserved for higher courses now has surfaced earlier in high school as interesting and practical explorations that could be tackled with the use of GSP. On top of that, as a result of their explorations, he found that his students had been led to a deeper understanding of the problem and its solutions.

Besides getting the positive result in the study, there are also some studies that showed negative results. For example, in the study [25] to examine the effects of using the Geometer's Sketchpad (GSP) and the graphic calculator (GC) in the learning of the vertex form of quadratic functions among field dependent (FD) and field independent (FI) cognitive style students, it was found that the students performed as well when using the GSP or the GC in the learning of quadratic functions by way of the visualization of graphs. The findings of this study also showed that the GSP and GC did not provide effective support to FD students in learning quadratic functions. It was suggested that more research be conducted on FDFI students in the usage of these learning tools. Various effective pedagogical strategies coupled with the usage of these tools could very well be an area to look into to help the FD students.

A similar research was conducted [26] which compared the use of the GSP software, the graphic Calculator and the traditional method to learn on the cross-section of a cone. Results of the study showed that the GSP software and the Graphic Calculator did not show a significant effect on the achievement of the students. Yuan [27] also discovered that there was no significant difference between the achievements of the GSP group and the group that were taught using the traditional method, on the topic of 'Quadratic Functions' and on 'Triangles'.

From the above findings, it may be concluded that the utilization of the GSP software has obtained mixed reviews on its effectiveness. Thus, the purpose of this study was to investigate the effectiveness of integrating a mathematical software which is Geometer's Sketchpad compared to the traditional approach in teaching and learning of Form 4 Additional Mathematics subject on the topic of 'Quadratic Functions'.

II. OBJECTIVES OF STUDY

Specifically, the objectives of this research are:

1. To compare students' mathematical performance utilizing the GSP and the conventional instructions in mathematics teaching and learning at the Malaysian secondary level;
2. To compare instructional efficiency of learning conditions utilizing GSP and conventional instruction in mathematics teaching and learning at the Malaysian secondary level;
3. To investigate the attitude of students towards learning GSP and conventional instruction in mathematics teaching and learning at the Malaysian secondary level;

A. *Research Hypotheses*

The five hypotheses to be tested in this study were:

1. There was no significant difference in performance scores between the GSP group and the traditional group;
2. There was no significant difference in scores obtained for conceptual skills between the GSP group and the traditional group;
3. There was no significant difference in scores obtained for procedural skills between the GSP group and the traditional group;
4. There was no significant difference in the number of problems solved between the GSP group and the traditional group; and
5. There was no significant difference in the number of errors committed between the GSP group and the traditional group.

III. SIGNIFICANCE OF THE STUDY

This study would contribute significantly to the existing knowledge when looking at the effect of utilizing technology for the teaching of mathematics, especially in a subject that is not a favorite amongst Malaysian students, namely Additional Mathematics. The research also had utilized a dynamic software that had been recommended by the Ministry of Education to be used for teaching mathematics. The results of this research would be very useful for all secondary mathematics teachers especially those teaching Additional Mathematics. In fact, the findings of this research would be useful to any teacher or researcher who had the intention of embarking on an experimental research, or an intervention programme.

IV. LIMITATION OF THE STUDY

A limitation of the study was in terms of accessible population and for schools that would have up-to-date computer laboratory facilities to conduct the research. Owing to the lack of enough Additional Mathematics students in form four in one neighboring school, the research had to be conducted using two groups from two neighboring schools. Thus, to control for location that can pose as a threat to internal validity of the experiment, these students were taken to the University in order to experience a common environment. The GSP group was then placed in a computer laboratory while the conventional group in another laboratory without computers. Another limitation of the study was in terms of the time the students were able to stay at the University. Since the students were shuttled to the University, they were only able to stay for the day, thus allowing the research to be conducted for only six hours.

V. METHODOLOGY

Under this section, the design of the study, population and sample of the study, materials and instruments are discussed separately.

A. *Design of the Study*

A true experimental design randomized post-test only control group design was used for this study with students randomly assigned into two groups. According to [28], this design allows for at least eight extraneous variables that may pose threats to the internal validity of the experiment to be controlled. In this design, the experimental group underwent learning using Geometer Sketchpad technology while the control group underwent learning using a conventional instructional strategy. This study used four phases for the experimental group, namely: 1) Introduction to Geometer Sketchpad; 2) Introduction to Quadratic Functions; 3) Integrated teaching and learning using Geometer Sketchpad with exercises; and 4) Assessment using a set of Quadratic Equation Test as the posttest. The conventional (control group), on the other hand, underwent only Introduction to Quadratic Functions (phase 2 undergone by the experimental group), followed by a session on teaching and learning with further exercises. During the time when the experimental group underwent the posttest (at Phase 4), the control group then was administered the same test. The data were analyzed using independent t-tests.

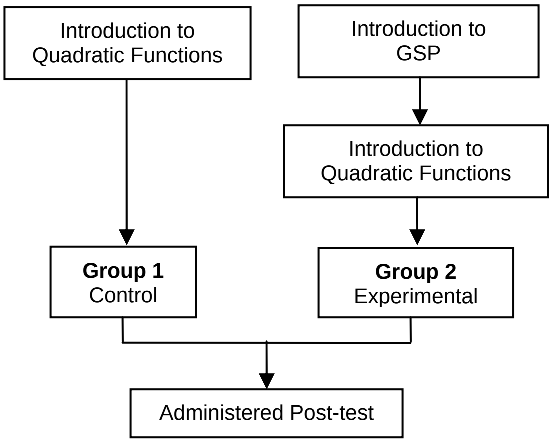

Fig. 1: Flow chart of research process

B. *Population and Sample of the Study*

The target population of this study was Form Four students in National Secondary School in Malaysia. The samples selected for this study were Form Four students from two schools. The students were brought to the university to participate in the learning sessions. They were then randomly assigned to two groups, namely the GSP (experimental) and conventional (control) groups. The total number of students in the GSP group was 45 students whilst the conventional group was 47 students.

C. *Materials*

The instructional materials for this study consisted of a set of lesson plan on the topic of Quadratic Functions for Form Four Additional Mathematics syllabus, and also a set of module prepared by the researchers. The module which consisted of the content of the lesson was distributed to the students to use as guide throughout the teaching and learning process.

During the first phase, the treatment group was initially introduced to the use of the GSP. Each student in the GSP group was provided with one GSP each. In this phase, the students were required to explore and be familiar with the use of the GSP and its functions. The conventional group followed teaching and learning session in the traditional teacher-centered approach.

In the second phase, students were introduced to the basic concept of the Quadratic Functions topic and mathematical problem solving sessions. During this teaching and learning phase (third phase), students were given assessment questions to evaluate the extent of short term learning. At the end of the treatment session during the fourth phase, students were given an achievement test in which they solve given problems, without using the GSP. Examples of some of the products produced by students during their activities are illustrated in the attached figures.

D. *Instruments*

The Paas [29] Mental Effort Rating Scale was used to measure cognitive load by recording the perceived mental effort expended in solving problems when doing the exercises in the exercise sheets during the teaching and learning phase. The PMER was a 9-point symmetrical Likert scale measurement on which the subjects rate their mental effort used in performing a particular learning task. It was introduced by Pass [29] and Pass and Van Merrenboer [30]. The numerical values and labels are assigned into different range from 1: very low mental effort to 9: very high mental effort. Performance was measured using a set test related to the topic taught. Three questions were posed which involved students having to show their understanding conceptually and procedurally. After answering each question, students were required to indicate the amount of mental effort invested for that particular question by responding to the nine-point symmetrical scale.

The questions were categorized as conventional problems similar to any standard examination given in the country.

VI. RESULT AND DISCUSSION

The results of the study are discussed based on the objectives and hypotheses stated. Analyses of the posttest achievement scores were done using the SPSS package.

The result of the independent-t test, comparing the posttest results of the two groups showed that there was no significant difference between mean performance scores (Table 1) of the control group ($M = 13.03$, $SD = 3.65$) compared to scores for the GSP group ($M = 11.78$, $SD = 4.10$; $t(92) = 1.55$, $p>.05$). In fact the mean score of the control group is higher than the result of the experimental group.

Table 1: Comparison of performance

Performance	Group	N	M	SD
Test	GSP	45	11.78	4.10
performance	Control	47	13.03	3.65

This finding seemed to support the works of [26] and [27], and contrary to the findings obtained by [14], [17] and [22].

Further analysis on the conceptual skills (students' understanding and appropriate use of mathematical concept) was also conducted. Data showed in Table 2 indicated that there was no significant difference between conceptual skills obtained by the control group ($M = 7.28$, $SD = 3.63$) as compared to that obtained by the experimental group ($M = 5.99$, $SD = 4.67$; $t(92) = 1.48$, $p = .142 > .05$). Even though no difference was found between the two groups, however the control group seems to achieve a slightly higher mean value than the GSP group.

Table 2: Comparisons of selected variables

Variables	Group	N	M	SD	SE
No. of problem solved	GSP	45	5.98	1.29	.19
	Control	47	6.28	1.08	.16
Total score of the conceptual knowledge	GSP	45	5.99	4.67	.70
	Control	47	7.28	3.63	.53
Total score of the procedural knowledge	GSP	45	18.4	1.39	.21
	Control	47	18.06	1.36	.19
Total score of the test	GSP	45	24.01	4.74	.71
	Control	47	25.34	3.78	.55
Number of errors committed	GSP	45	1.95	1.54	.23
	Control	47	1.52	.898	.13
Mental Load	GSP	45	5.61	2.03	.30
	Control	47	4.46	1.48	.28
2D Efficiency	GSP	45	-0.28	1.22	.181
	Control	47	0.43	0.95	.178
3D Efficiency	GSP	45	-0.56	1.24	.216
	Control	47	0.61	0.87	.198

Besides the conceptual skills, the procedural skills, i.e. the extent students were able to employ and follow the procedural steps when performing each activity, for instance the procedural skill of plotting the graphs, were analyzed. Data showed that there was no significant difference between procedural skills obtained by the control group (M = 18.06, SD = 1.36) compared to that obtained by the experimental group (M = 18.4, SP = 1.39; $t(92) = 1.174$, $p = .243 > .05$). Here, it was observed that the mean obtained by the experimental group was slightly higher than the mean of the control group.

In fact, Table 2 also showed the comparison of means obtained by the control group and those obtained by the experimental group for another two variables, namely: number of problems solved and number of errors committed. For the variable number of problems solved, it was also found that there was no significant difference between the mean of the control group (M= 6.28, SD = 1.08) and the mean of the GSP group (M = 5.98, SP = 1.29; $t(92) = 1.21$, $p = .230 > .05$). The experimental group was observed to solve slightly fewer problems. For the variable number of errors committed, there was also no significant difference between the mean of the two groups. Again, even though there was no significant difference observed, however, the mean of the GSP group was seen to be slightly higher (M = 1.95, SD = 1.54), than the control group (M = 1.52, SD = 0.898), $t(92) = -1.65$, $p = .103 > .05$). Thus, the experimental group was also seen to commit slightly more errors compared to the control group.

The second objective of the research was to compare, the instructional efficiency of the learning conditions utilizing the GSP and conventional instruction in mathematics teaching and learning. Here the mental load was measured using the Paas Mental Effort Rating Scale. Results showed that even though there was no significant difference between the perceived mental load of the GSP group compared to that perceived by the control group, however, the mental load of the GSP group was seen to be slightly higher (M = 5.61, SD = 2.03) than the mental load perceived by the control group (M = 4.46, SD = 1.48). A higher mental load was perceived might be due to the fact that the experimental group was putting in a higher mental effort when the group was initially introduced to the GSP for the first time and within a limited time, the group had to familiarize themselves with the use of the GSP. This phase was then followed by the introduction of the basic concepts of the Quadratic Functions. The group was then given exercise questions to solve and during this process, the three dimensional (3D) efficiency was measured. The control group on the other hand did not have to go through the first phase. The group's lesson started straight away with the introduction to the basic concepts of the Quadratic Functions.

Table 2 also showed the 3D Efficiency mean score for the experimental group to be -0.56 while the control group to be 0.61. The two dimensional (2D) Efficiency mean score, i.e. the mean obtained by the groups, taking into consideration only the test score, was also measured. The experimental group obtained -0.28 for the 2D Efficiency measured. As for the control group, the means were 0.61 and 0.43 respectively. Here again, for both instances, the experimental group seemed to perceive a higher effort on the group's part to perform the task as compared to the perception of the control group to perform their tasks.

It would be interesting to highlight here that there seemed to be homogeneity amongst all the results obtained or perceived by the control group as compared to the experimental group. The slight heterogeneity within the experimental group might be due to a slightly wider range in achievements and perceptions amongst the individuals within the GSP group.

For the final objective, the attitudes of students towards the respective teaching approaches used was measured according to the four dimensions of students attitudes vis-à-vis level of enthusiasm, level of enjoyment, level of anxiety and level of avoidance. In this investigation, level of enthusiasm refers to the extent students were enthused to continue learning using the respective approaches. Level of enjoyment refers to the extent students had enjoyed the approached used to teach the respective groups and would choose to continue with the lesson in the same way. Level of anxiety refers to the extent the approach had imposed and created anxiety during learning. Level of avoidance refers to students' perceptions that the respective approaches were a waste of time and a fruitless effort. Results are illustrated in Table 3.

Table 3: Mean and SD of students' attitudes towards the teaching and learning approaches

	Control		GSP	
Levels	Mean	SD	Mean	SD
Enthusiasm	3.29	0.612	3.52	0.526
Enjoyment	3.28	0.610	3.40	0.565
*Anxiety	1.87	0.386	1.93	0.474
*Avoidance	1.77	0.612	1.69	0.526

Table 3 showed that for the level of enthusiasm, the students' perception of utilizing the GSP (M = 3.52) was much higher than the traditional group (M= 3.29). For level of enjoyment the GSP group obtained (M = 3.40) which is also higher than the mean of the traditional group (M = 3.28). Findings confirmed that GSP students were more enthused and were enjoying their lessons more than students who had undergone the traditional approach. For the items on anxiety, students under the traditional approach scored lower (M = 1.87) than the GSP group (M = 1.93). This shows that the traditional group perceived lesser anxiety than the GSP group. However, for the level of avoidance, the mean of the GSP group (M = 1.69) is lower than that perceived by the traditional group (M = 1.77). This indicated that the GSP group would not avoid using the software to learn with. The positive attitudinal change detected in this study supported the works of [15] and [18].

Overall, there seemed to be higher homogeneity that existed amongst the experimental group for all the four dimensions measured, as compared to the control group. A smaller dispersion were seen which might account for the fact that the group, as a whole, was having similar attitudes toward the use of GSP for learning geometry.

VII. CONCLUSION

It is crucial to note here that the respondents are Form Four students selected form a nearby school. They had been brought to the university to experience a six-hour session of teaching and learning. Within the six hours, the students from the experimental group needed to be familiar with the use of the computer; they also needed to understand the mathematics concepts, and at the same time to familiarize themselves with the use of the GSP. For these students, using GSP is a totally new and exciting experience as observed from the attitudinal measures, but they did not have enough time to be very familiar and explore further the GSP, and thus would be able to benefit fully from its utilization during teaching and learning process. Thus, time's constraint might be one of the factors why this study came out with negative impact on the use of technology.

VIII. IMPLICATIONS

In response to the foreseeable change of global knowledge economy, it is imperative that the utilization of ICT in the teaching and learning process of Mathematics be practised since the use of dynamic geometry softwares have been explicitly indicated in the new Malaysian secondary school syllabus [10]. Besides, the Ministry of Education Malaysia has also secured the license for these softwares to be used in the Malaysian schools. The findings of this study have raised implications to the way the teaching and learning processes are supposed to be carried out in the schools. Notwithstanding the limitations highlighted above, the use of GSP has revealed a positive attitudinal change amongst the students researched. This positive outlook is very promising in lieu of the findings that the students were reported to be experiencing a higher mental load compared to the ones who did not have to familiarize themselves to use the computer, the GSP software and at the same time having to learn a new topic on higher level mathematics.

IX. RECOMMANDATION

Further studies need to be done, especially on the time duration needed for students to learn and explore using GSP in learning mathematics. Furthermore, more research also need to be conducted in normal classroom settings in Malaysian schools, in order to explore further the utilization of the GSP in mathematics learning. However, findings from this study can elicit ideas to teachers and researchers on the needs to use ICT in teaching and learning mathematics.

Future research needs to ensure that the experimental group be: firstly, familiar and comfortable with the use of the computer per se; and secondly, familiar with whatever software that is supposed to be the treatment for the experimental group. Once the subjects are familiar and have the opportunity to explore the software, then the subjects will not be overly anxious into wanting to concentrate on too many new things at the same time. The subjects will then have to focus and concentrate on the content that is supposed to be learned. The time given for the experimental group and the control group to learn whatever content taught will be made the same.

APPENDIX

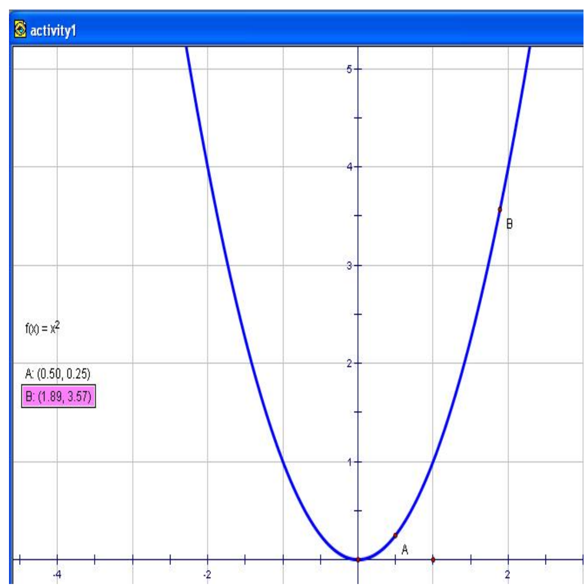

Fig. 2: Graph to illustrate student's work on Lesson 1

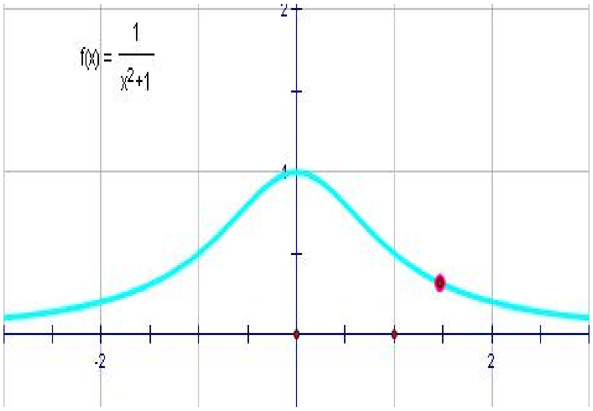

Fig. 3: Graph to illustrate student's work on Lesson 2

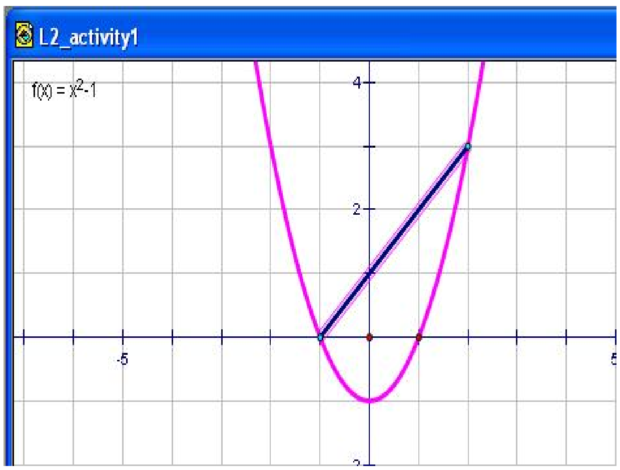

Fig. 4: Graph to show student's work on Lesson 3

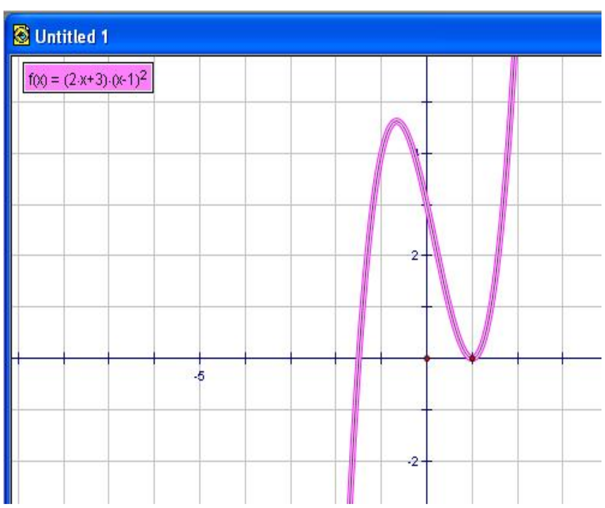

Fig. 5: Graph to illustrate student's work on Lesson 8

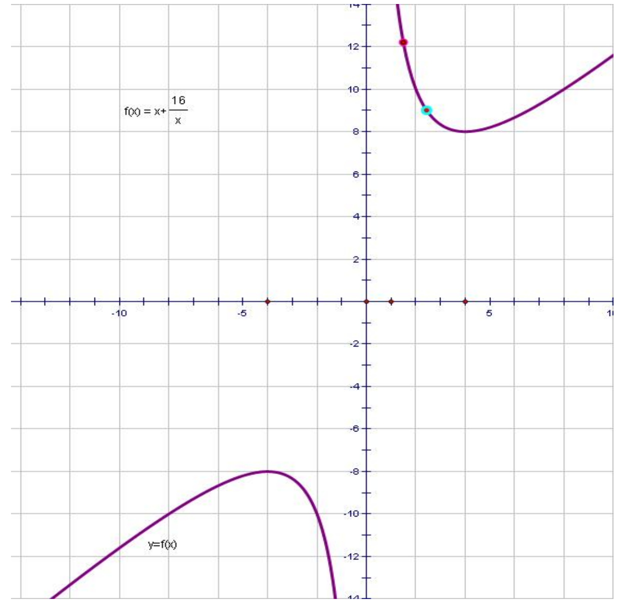

Fig. 6: Graph to show student's work on Lesson 11

REFERENCES

[1] Becta. (2007, 1 Oct.). What research says about using ICT in Mathematics. 2003. [Online]. Available http://partners.becta.org.uk/page_document/research/wtrs_maths.pdf.

[2] R.J. Ittigson, and J.G. Zewe, Technology in the mathematics classroom. in L.A. Tomei, (ed), *Challenges of Teaching with Technology Across the Curriculum Issues and Solutions*. Hershey: Information Science and Publishing. 2003.

[3] National Council of Teachers of Mathematics, NCTM Standards. *Principles and Standards for School Mathematics.* 2000.

[4] A. Oldknow, and R. Taylor, *Teaching Mathematics with ICT*. London: Continuum. 2000.

[5] H. Becker, How Computers are used in United States Schools: Basic data from the 1989 I.E.A. Computers in Education Survey. *Journal of Educational Computing Research*, 7(4), 1991, pp. 385-406.

[6] D.H. Jonassen, Computers a mindtools for schools: Engaging critical thinking. Upper Saddle River, N.J.:Merrill, 2000..

[7] D.H. Jonassen, K.L. Peck, and B.G. Wilson, *Learning with technology: A constructivist perspective.* Upper Saddle River, N. J.: Merrill, 1999.

[8] A.T. Rohani, M.A. Ahmad Fauzi, A.B. Kamariah & M.Y. Aida Suraya. Learning mathematics through utilization of technology: Use of Autograph technology versus handheld graphing calculator. In *Proceedings of the 7th WSEAS International Conference On Education And Educational Technology (EDU'08)*, Venice, 2008, pp.71-76.

[9] L.H. Yeung, The use of Geometer's Sketchpad to facilitate new learning experience in geometry. Master of Science in Information Technology in Education, Faculty of Education, The University of Hong Kong. 2003.

[10] Kementerian Pelajaran Malaysia. *The Integrated Curriculum For Secondary Schools – Curriculum Specification (Additional Mathematics)*, Kuala Lumpur. 2003.

[11] *Geometer's Sketchpad Reference Manual. (Fall)*. California: Key Curriculum Press, *2001*.

[12] C. Giamatti, Conjectures in Geometry and the Geometer's Sketchpad,. *Mathematics Teacher*, Vol. 88, No. 6, pp. 456-458, 1995.

[13] W. Finzer, and D. Bennett, From Drawing to Construction with The Geometer's Sketchpad.. *Mathematics Teacher*, V88, n5, pp. 428-431, 1995.

[14] M. Lester, The Effects of the GSP Software on Achievement Knowledge of High School Geometry Students. Dissertation Abstract International, DAI-A 57106, University of San Francisco, 1996.

[15] A. Yousef, The Effect of the GSP on the attitude toward Geometry of High School students. *Dissertation Abstract International, A 58105*, Ohio University, 1997.

[16] M.A. Ahmad Fauzi, A.T. Rohani, A.B. Kamariah and M.Y. Aida Suraya, Perceived ease of use and usefulness of dynamic mathematical software: experiences of Malaysian secondary students. *In Proceedings of the 7th WSEAS International Conference on Education and Educational Technology (EDU'08)*, 2008, pp.77-82.
[17] J. Dixon, English Language Proficiency and Spatial Visualization in Middle School Students' Construction of the Concepts ofReflection and Rotation used the GSP. *Dissertation Abstract International, DAI-A 56111*, University of Florida, 1996.
[18] M. Growman, Integrating Geometer's Sketchpad into a Geometry Course for Secondary Education Mathematics Majors *Association of Small Computer uses in Education (ASCUE) Summer Conference Proceedings*, 1996.
[19] N. Norazah, Z. Effandi, A.E. Mohamed, and M.Y. Ruhizan. Pedagogical Usability of the Geometer's Sketchpad (GSP) Digital Module in the Mathematics Teaching. *In Proceedings Of The 7th WSEAS International Conference On Education And Educational Technology (EDU'08)*, 2008, pp. 240-245.
[20] J. White, and V. Norwich, Computer Activities for College Algebra and Precalculus, 1997.
[21] A.L. Quinn, Using dynamic geometry software to teach graph theory: Isomorphic, bipartite, and planar graphs. *The Mathematics Teacher*, 90(4), 1997, p. 328.
[22] M.A. Norhayati, Pengajaran dan & pembelajaran matematik berbantukan komputer: Keberkesanan perisian "The Geometer's Sketchpad" untuk tajuk penjelmaan. [Teaching and learning of mathematics with the aid of computer: Effect of The Geometer's Sketchpad for the topic on 'Penjelmaan' *Disertasi.* Universiti Kebangsaan Malaysia, 2003.
[23] F. Almeqdadi (2005, September), The effects of using the Geometer's Sketchpad(GSP) on Jordanian students' understanding some geometrical concepts. [Online]. Available http://www.cimt.plymouth.ac.uk/ journal/almeqdadi.pdf.
[24] D.C. *Purdy*, Using the geometer's sketchpad to visualize maximum-volume problems. *The Mathematics Teacher*, 93(3), 2000, p.224.
.[25] B.T. Teo, and S.F. Fong, The effects of Geometer Sketchpad and Graphic Calculator in the Malaysian Mathematics classroom. *Malaysian online Journal of Instructional Technology*. Vol. 2, No. 2, 2005, pp 82 – 96.
[26] S. Ling, Enhancing the Learning of Conic with Technology. California: California State University Dominguez HilKey Curriculum Press. 2001. *The Geometer's Sketchpad Reference Manual.* Emeryville: Key Curriculum Press, 2004.
[27] Y. Yuan. (2007, Oct 1), Integrating technology into mathematical Instruction. A study of its effect on students' mathematics achievement and attitude at the eight grade in Taiwan. [Online]. Available http://www.hiceducation.org/edu_proceeding/Yuan%20Yuan.pdf.
[28] D.T. Campbell, and J.C. Stanley, *Experimental and Quasi-Experimental Designs for Research*, Chicago: Rand McNally and Co., 1966.
[29] F. Paas, Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive-load approach. *Journal of Educational Psychology*, 84, 1992, pp. 429–434.
[30] F. Paas, and J.J.G. van Merriënboer, Variability of worked examples and transfer of geometrical problem solving skills: A cognitive-load approach. *Journal of Educational Psychology,* 86, 1994, pp. 122–133.

Kamariah Abu Bakar is a Professor at the Faculty of Educational Studies, Universiti Putra Malaysia and an associate researcher at the Institute of Mathematical Research (INSPEM). Besides teaching, she also has a wide experience in student supervision, research and consultancy, and administration. She has been involved in research and consultancy work both nationally and internationally in the area of Science Education, Mathematics Education, and the utilisation of Information, Communication and Technology in education, more specifically in teaching-learning strategies

Rohani Ahmad Tarmizi is an Associate Professor at the Faculty of Educational Studies, Universiti Putra Malaysia. Currently she serves as the Head of the Laboratory of Innovations in Mathematics Education at the Institute of Mathematical Research, UPM. She has been involved in research and consultancy both nationally and internationally in the area of mathematics education, educational research measurement and assessment and statistical analysis for social sciences.

Ahmad Fauzi Mohd Ayub is a senior lecturer at the Faculty of Educational Studies, Universiti Putra Malaysia is also an associate researcher at the Institute of Mathematical Research (INSPEM). His research interests include multimedia education, integrating technology in Mathematics Education and online learning

Aida Suraya Md Yunus is an Associate Professor at the Faculty of Educational Studies, Universiti Putra Malaysia. Currently she serves as the Head, Department of Science and Technical Education and is an associate researcher at the Institute of Mathematical Research (INSPEM) and the National Higher Education Research Institute, Universiti Sains Malaysia. She has been involved in research and consultancy works, both nationally and internationally in the area of Mathematics Education and integrating technology in Mathematics Education.