Instructional Efficiency of Utilization of Autograph Technology Vs Handheld Graphing Calculator for Learning Algebra

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Abstract**—** Learning mathematics is a major focus of educational institution at all levels. There is plenty of evidence that teaching secondary or college level mathematics with dynamic software can be effective, more efficient and above all it creates more enjoyable teaching and learning environment. Conceptually and pedagogically, technology-assisted learning has provided positive impact on mathematical learning. Technology-assisted approach helps move mathematic teaching and learning out of its "stand and deliver" mode to active group learning developing individuals' potential as effective problem solvers and critical thinkers. The new technologies such as computers or calculators might affect the education system hence if used strategically the technologies provide learners the power of controlling what they are learning. This study aimed to investigate the instructional efficiency index of an interactive software Autograph and a hand-held graphing calculator in comparison to the conventional way for teaching algebra. The Autograph has 2D and 3D graphing capabilities for topics such as functions, transformations, conic sections, vectors, slopes and derivatives. On the other hand, graphing calculator is a handy device that can be use for teaching mathematics which is able to create geometric figures, graph functions, inequalities or transformations of functions. The Paas Mental Effort Rating Scale developed by Paas and Merrienboer, 2004 were used to measure instructional efficiency of the three teaching modes utilized in the study. Hence a true-experimental research design was used for this study with students selected at random to be assign to three groups. Four phases were conducted: 1) Introduction to Software, 2) Introduction to quadratic Functions, 3) Integrated teaching and learning using software, 4) Testing using Achievement Test and the Paas Mental Effort Rating Scale. The data were analyzed using ANOVA and post-hoc analyses. Teaching and learning utilizing the graphing calculator was found to be instructionally efficient significantly, $F(2, 98) = 11.1$, $p < .000$ compared to the conventional and Autograph mode. Conventional strategy incurs low mental effort and high performance compared to used of Autograph. Graphing calculator condition thus far imposed relative low mental effort with high performance. Autograph condition imposes high mental effort with low performance. 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.

Keywords**—** Technology-assisted learning, mental load, instructional efficiency index, graphing calculator, Autograph.

I. Introduction

TECHNOLOGY in education had vast impact on learners worldwide. Many people believed that technology will only brings bad influenced on students in future, while some believe that technology will assist students in their learning. All students learn differently, and technology is to assist students who have difficulties in learning. Technology has many different effects on education, specifically, in enhancing students learning. When technology and appropriate teaching methods are integrated in teaching and learning, positive impact maybe observed on both cognitive and affective domain.

A. Impact of Technology in Teaching and Learning

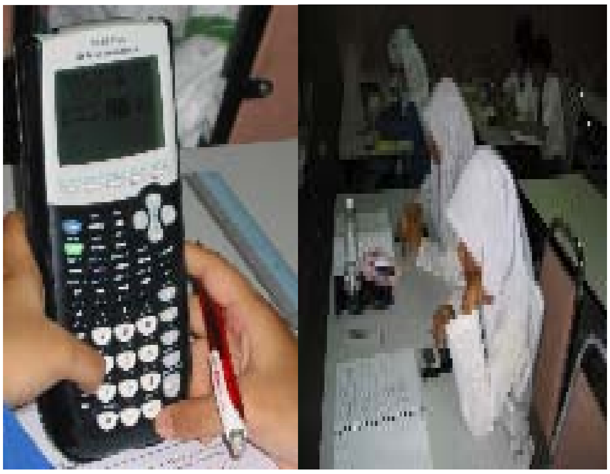
Use of technology as a tool or a support for communicating with others allows learners to play active role rather than the passive role of recipient of information transmitted by a teacher, textbook, or broadcast. The student is actively making choices about how to generate, obtain, manipulate, or display information. Technology use allows many more students to be actively thinking about information, making choices, and executing skills than is typical in teacher-led lessons. Moreover, when technology is used as a tool to support students in performing authentic tasks, the students are in the position of defining their goals, making design decisions, and evaluating their progress. The teacher's role changes as well. The teacher is no longer the centre of attention as the dispenser of information, but rather plays the role of facilitator, setting project goals and providing guidelines and resources, moving from student to student or group to group, providing suggestions and support for student activity. As students work on their technology-supported products, the teacher rotates through the room, looking over shoulders, asking about the reasons for various design choices, and suggesting resources that might be used.

Prepelita-Raileanu (2008) suggested that teachers are to be educated concurrently with the increase use of information, communication technology (ICT). The role of teachers as organizers and distributor of the teaching have to be developed concurrently with the integration of ICT in any educational programmes. However much has to be explored and ICT, as any other tools in teaching and learning must be utilized and adapted to serve educational goals. Technology indeed has changed the way classrooms operate, integrating multimedia during learning, online accessibility thus making teaching and learning more interactive and participatory (Butler, 2008).

The rapid progress of technology has influenced the teaching and learning of mathematics. Many efforts are being made to enhance the learning experiences for students in learning mathematics. In the traditional teaching of mathematics, students are passive recipients when teacher passes complete information to them. Meanwhile, with the integration of technology such as computers and calculators, students are encouraged to get deeper understanding of concepts. Furthermore, technology can also develop a better understanding of abstract mathematical concepts by their visualization or graphic representation where it shows the relationships between objects and their properties. By having deeper understanding of concepts, this will increase the ability of the students when working with mathematics knowledge. Findings from Abu Bakar, Tarmizi, Ayub, Yunus (2008), also confirmed that students learning mathematics with the integration of technology were found more enthused and were enjoying their lessons more than students who had undergone the traditional approach. Consistently on students' level of avoidance, the mean of the group using technology was lower than that those perceived by the traditional group. This indicated that the technology group would not avoid using the software during mathematical learning activity.

B. Graphing Calculator in Mathematics Learning

Graphing calculator technology is a hand-held mathematics computer that can draw and analyses graphs, computes the values of mathematical expression, solves equations, perform symbolic manipulation, perform statistical analyses, programmable and communicates information between devices (Jones, 2003). Numerous studies in many developed countries have shown positive impact on using graphing calculator in the classroom and in examination (Quesada & Maxwell, 1994; Merriweather & Tharp, 1999; Hennessy, 2000; Graham & Thomas, 2000; Doerr & Zangor, 2000).



Graphing calculator is powerful as a teaching tool. The graphing calculator is not only a teaching tool in the classroom in the hands of the teacher, it is also a teaching tool in the hands of students when given through investigations, concept development and guided discovery exercises, explorations, open-ended homework exercises, and extended modeling projects. Simply stated, it is considerably more versatile as a teaching or learning tool. On the other hand, the conventional strategy does not have the needed capabilities since it is using chalk and talk tools. It is using whiteboard that does not allow students to see a clear and pedagogically sound connection between input parameters and output results of mathematical concepts.

Graphing calculators are approximately the same size of a scientific calculator but a graphics screen replaces that of a numerical display screen. This feature, coupled with built-in software, is capable of undertaking all kinds of mathematical work. Some of the tasks made possible are graphing functions, tabulating functions, analyzing statistical data, manipulating matrices, equation-solving, calculus, probability and complex analysis. Without doubt, technology of this kind would be of the most utmost importance to secondary schooling. Because of its comparably cheap price, in comparison to a personal computer, it is not unreasonable for every student who is studying mathematics to own their own graphics calculator or for their school to be able to supply one to each student.

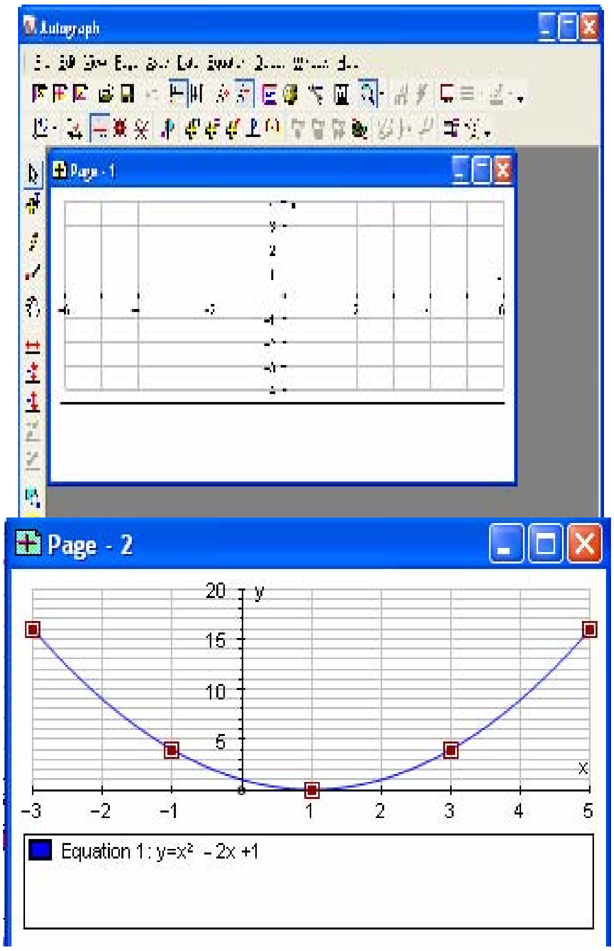
It can be said that the use of a graphing calculator in a mathematics classroom transforms the class to that of a laboratory, similar to that of a science class. Students could work in small groups where they can investigate patterns, analyze results and solve problems, thereby constructing their own mathematical understanding. One of the greatest assets of a graphing calculator is its ability to generate graphs on their large graphics screen. The speed of which graphs can be generated, together with the ability to examine the finer detail of the graph, make for quicker analysis of data by the student, therefore making a connection between an algebraic equation and the graph. This eliminates the sometimes tedious process of graphing by hand. Multiple graphs could be displayed simultaneously and quick comparisons could be drawn. A student could examine mathematical phenomena quickly and be encouraged to make their own further investigations.

Briggs and Bennett (1999), state that every piece of technology used takes away teaching time. But certainly a graphing calculator does not fall into this category when it is implemented properly. This is a common misconception among those who have never used it or who have been unsuccessful in their attempt. Learning to use the graphing calculator in the context of mathematics can be a teaching enhancement, not something that takes away from teaching.

A comprehensive review of the research on handheld graphing technology in secondary mathematics instruction (Burrill, Allison, Breaux, Kastberg, Leatham, & Sanchez, 2002) indicated that there is improved student conceptual understanding when students use graphing calculators with curriculum specifically designed to take advantage of the technology. "The type and extent of gains in student learning of mathematics with handheld graphing technology are a function, not simply of the presence of handheld graphing technology, but of how the technology is used in the teaching of mathematics" (Burrill, et al., 2002).

C. Autograph Software in Mathematics Learning

Autograph is another technology which is dynamic software for teaching calculus, algebra and coordinate geometry. Its environment has 2D and 3D graphing capabilities for topics such as transformations, conic sections, vectors, slope, and derivatives. In real-time, users can observe how functions, graphs, equations, and calculations. Autograph can be used for drawing statistical graph, functions, and vector and for transforming shapes. It also enables users to change and animate graphs, shapes or vectors already plotted to encourage understanding of concept. In mathematics class the use of mathematical software enable students to visualize and further understand mathematical phenomenon in real life.



Teaching by integrating Autograph in schools might increase the effectiveness and the quality of teaching. As mathematics class needs lots of interaction, reasoning, observation the above view clearly indicates that interactive software like Autograph can be useful in teaching and learning mathematics effectively. Use of Autograph help teachers in making students attentive towards the interactive whiteboard and acts as a medium of interaction among students or between teacher and the students with rapid responses. Teacher can attract the whole class to the interactive whiteboard just by using the mouse and keyboard, save the work and can be viewed later on. These facts clearly indicates that Autograph is an extremely useful educational tool for both mathematics teachers and students which help teachers to present the content for the whole class easily and students understand better due to its visual demonstration.

The use of Autograph is similar to use of Geometer's Sketchpad software (GSP) which allows learners to acquire skills and knowledge in using the computers whilst concurrently explore the potentials of the software (Nordin, Zakaria, Embi & Mohd Yassin, 2008; Ayub, Tarmizi, Abu Bakar & Yunus, 2008). Their findings indicated that integration of GSP in teaching mathematics can be aided by the module developed and that learning of graphs and functions through utilization of technology simplified learning and increase students understanding. Specifically, Stacey (2007) contended that the use of software in mathematical learning enhanced the understanding of mathematical concepts related to variables and functions as well as provides motivation for the learning of Algebra.

D. Mathematial Knowledge/Performance and Mental Load

Currently, there is more interest in how students acquire knowledge, how procedural and conceptual knowledge are linked and the mutual benefits of this linkage (Hiebert & Carpenter, 1992; Post & Cramer, 1989; Hiebert & Lefevre, 1986).

Conceptual knowledge is defined by Hiebert and Lefevre (1986) as knowledge that is rich in relationship. It can be thought of as a connected web of knowledge, a network in which students are able to apply and link mathematical relationships to a variety of problems. Conceptual knowledge is characterised by links and a unit of conceptual knowledge cannot be an isolated piece of information. Furthermore, they emphasised that a piece of information is part of conceptual knowledge only if the holder recognises its relationship to other pieces of information. Hiebert and Lefevre (1986) note the following example of conceptual knowledge such as the construction of a relationship between the algorithm for multi-digit subtraction and knowledge of the positional values of digits (place value).

It is also assumed that conceptual knowledge is stored in some form of relational representation, like schemas, semantic networks or hierarchies (Byrnes & Wasik, 1991). It can be largely verbalized and flexibly transformed through processes of inference and reflection due to its' abstract nature and the fact that it can be consciously accessed. Therefore, it is not only bound up with specific problems but also can be generalised for a variety of problem types in a domain (Baroody, 2003).

On the other hand, as defined by Hiebert and Lefevre (1986), procedural knowledge in mathematics is composed of two parts namely the formal language or symbol representational, of mathematics and the algorithms, or rules, for completing mathematical tasks. It means that procedural knowledge can be classified as structural knowledge and algorithmic knowledge. The former is knowledge related to the meaning and appropriate use of mathematical symbols. It implies only an awareness of superficial features, but not knowledge of meaning or underlying structure. For example, we can write the string $x+2=3$ for some integer *x*, however the notation $2+=x3$ doesn't give an appropriate mathematical statement that falls under the first type of procedural knowledge. The algorithmic knowledge refers to step-by-step instructions that define precisely how to complete mathematical tasks or exercises in a predetermined linear sequence. For example, students who are able to do the algorithm for determining the value of *x* in $x+2=3$ is said to have the second type of procedural knowledge.

Procedural knowledge can also be described as the knowledge of operators and the conditions under which these can be used to reach certain goals (Byrnes & Wasik, 1991). This type of knowledge to some degree is said to be automated as it enables people to solve problems quickly and efficiently (Schneider & Stern, 2005; Hiebert & Carpenter, 1992). According to Johnson (2003), automatization is accomplished through practice and allows for a quick activation and execution of procedural knowledge. In addition, as compared to the application of conceptual knowledge, its application involves minimal conscious attention and few cognitive resources. The automated nature of procedural knowledge implies that it is not or only partly open to conscious inspection and hence can be hardly verbalised or transformed by higher mental processes.

Mental load refers to the aspect of cognitive load that originates from the interactions between task and subject characteristics (Paas et al., 2003b; Sweller et al., 1998; Paas & van Merrienboer, 1994). Paas and van Merrienboer (1994) state that mental load can be determined on the basis of our current knowledge about task and subject characteristics. Thus, it provides an indication of the expected cognitive capacity demands and can be considered an a *priori* estimate of the cognitive load.

Mental effort is the aspect of cognitive load that refers to the amount of cognitive capacity or resources which is actually allocated to accommodate the demands imposed by the task (Paas et al., 2003b; Sweller et al., 1998; Paas & van Merrienboer, 1994; Tarmizi & Sweller, 1988). Therefore, it can be considered to reflect the actual cognitive load. Mental effort is measured while participants are working on task (Paas et al., 2003b). Whereas, performance can be defined in terms of learner's achievements, such as number of correct test items, number of errors, and time on task. Further, it can be determined while learners are working on a task or thereafter.

According to Paas and van Merrienboer (1994, 1993), the intensity of effort being expended by learners can be considered the essence to get a reliable estimate of cognitive load. It is also believed that the measure of mental effort can yield important information about cognitive load that is not necessarily reflected in performance and mental-load measures (Paas et al., 2003a).

Based on cognitive load theory, cognitive load can arise from three sources during instruction: intrinsic, extraneous and germane cognitive load (Paas et al., 2004, 2003a; Sweller et al., 1998). The first source of cognitive load is intrinsic cognitive load which is connected with the nature of the material to be learned. It is related to the integral complexity of an idea or set of concepts, and reflects the difficulty of learning the concept(s). This means that the existence of this cognitive load is due to the mental demands or the complexity of the information itself. For example, the mental calculation of 2 + 4 has lower intrinsic load than solving a simultaneous linear equation. Thus, intrinsic cognitive load is unchangeable.

Element interactivity is the driver of this category of cognitive load (Paas et al., 2003a; Sweller, 1994). Different materials is said to differ in their levels of element interactivity. It primarily depends on the number of elements that must be simultaneously processed in working memory. This, in turn, depends on the extent of element interactivity of the material or task that must be learned. This would imply that the intrinsic cognitive load cannot be altered by instructional manipulations. The higher the element of interactivity contained in a material means the higher is its intrinsic cognitive load. However, a simpler learning task that omits some interacting elements can be chosen to reduce this type of load (Paas et al., 2003a). Thus, developing cognitive schemas that incorporate the interacting elements are the only way to foster understanding (Paas et al., 2003a; Sweller, 1994). It is by this process that human cognitive architecture handles complex material that appears to exceed the capacity of working memory.

The cognitive or mental load are measure based on the assumption that people are able to introspect on their cognitive processes and to report the mental effort expended (Brunken et al., 2003; Paas et al., 2003a; Sweller et al., 1998). These measures typically use rating scale techniques to report the experienced effort or the capacity expenditure. Paas (1992) was the first to demonstrate this finding in the context of cognitive load theory. He developed a 9-point symmetrical category Likert scale on which subject rates mental effort used to perform a particular learning task. The rating scale was a modified version of Bratfisch, Borg and Dornic's (1972) scale for measuring perceived task difficulty. The numerical values and labels assigned to the categories ranged from very, very low mental effort (1) to very, very high mental effort (9). The use of rating scale techniques in cognitive load research sometimes appears to be questionable (Paas et al., 2003a; Sweller, 1998). However, it has been demonstrated that people are quite capable of giving a numerical indication of their perceived mental burden (for example, Gaupher & Braune, 1984).

II. PURPOSE

The purpose of this study is to investigate the instructional efficiency index of using graphing calculator (TI-84 Plus) and Autograph Software in teaching and learning of mathematics on Form Four secondary school students' in learning Quadratic Functions. Specifically, the objective of this study mainly is to compare the effects of utilizing the two technologies i.e. the graphing calculator and Autograph software on various performance measures in learning of Quadratic Functions topic.

Research hypotheses of this study are:

i. There is significant difference in mean performance on groups using graphing calculator technology, Autograph technology and the conventional method in learning mathematics.
ii. There is significant difference in measure of mental load on groups using graphing calculator technology, Autograph technology and the conventional method in learning mathematics.
iii. There is significant difference in instructional efficiency index on groups using graphing calculator technology, Autograph technology and the conventional method in learning mathematics.

III. METHODOLOGY

A. Design of the Study

Experimental design was used for this study with students selected at random to be assign to three groups. The experimental group underwent learning using Autograph and graphing calculator technology while the control group underwent learning using conventional instructional strategy. Four phases were conducted: 1) Introduction to Software, 2) Introduction to Quadratic Functions, 3) Integrated teaching and learning using software and Learning Activity Module, 4) testing using Achievement Test and the Paas Mental Effort Rating Scale. The data were analyzed using ANOVA and post-hoc analyses.

Example of Learning Activity Module using Graphing calculator:

Plot the graph of a quadratic function $\mathbf{f(x) = x^2 + 1}$ by using the Graphing calculator given the following values:

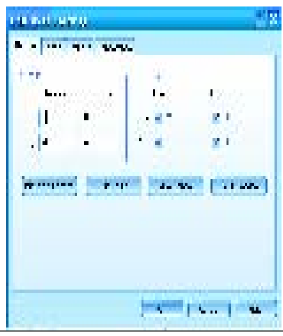
x	-4	-2	0	2	4
f(x)	17	5	1	5	17

<table>
<tr><th>STEPS</th><th>INSTRUCTION</th><th>DISPLAY NOTES</th></tr>
<tr><td rowspan="2">1
To key in the function</td><td>1. Press Y=</td><td>Y =</td></tr>
<tr><td>2. Insert the function by pressing $x^2 + 1$</td><td>X, T, Θ, n x^2 +   1</td></tr>
<tr><td rowspan="3">2
To display and compare the table.</td><td>3. Set table setup by Press 2ND Press TBLSET (Notes: TblStart-the first value of the value x to appear in table; Tbl-the increment for the independent variable x.)</td><td>2ND → TBLSET
Insert: TblStart = -4; Tbl = 2</td></tr>
<tr><td>4. Display the table by Press 2ND Press TABLE</td><td>2ND → TABLE</td></tr>
<tr><td>5. Compare the table given in question with the table displayed.
6. Move the cursor by Press ▲ , ► , ▼ , ◄</td><td>▲ ► ▼ ◄</td></tr>
</table>

3 To plot points on the graph.	7. Set the windows setting to ZDecimal. Press ZOOM Press 4	ZOOM → 4 : ZDecimal

Example of Learning Activity Module using Autograph:

Plot the graph of quadratic function **f(x) = x^2 – 6x + 9** using Autograph, given the range $0 \le x \le 6$

	INSTRUCTION	DISPLAY NOTES
1	Click icon NEW 2D GRAPH PAGE to create a new 2D page open with 2D toolbar and this standard x-y axes	
2	Then click the icon ENTER EQUATION to create a equation. Then click OK	
3	To change the scale for axes, choose the icon EDIT AXES to bring up the dialogue box. To change the range of *x*, just set the maximum and minimum value x manually.	

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 assigned to either of the three groups whereby group one were following the graphing calculator mode of learning, group two followed the Autograph learning mode and the third group was the conventional learning group. The total number of students in group one was 41 students, group two was 39 students and group three was 47 students.

C. Procedures

Four phases were conducted. In the first phase, the treatment groups were first introduced to the software. Each student in GC group was provided with one graphing calculator each. Students in Autograph group were provided with one computer installed with Autograph software. In this phase, the students were required to explore and get familiar with the graphing calculator buttons and its functions and same also for Autograph group.

Then in second phase, students were introduced to the basic concept of the Quadratic Functions topic. In the teaching and learning using software phase, students were thought with constructivist approach where they required to use exploratory and discovery learning on the topic. During the teaching and learning phase, students were given assessment questions to evaluate extent of short term learning. At the end of the learning or treatment session, students were given an achievement test. Teaching and learning phase for Autograph group were same with the GC group. The control group's students were also guided by the same instructional format with one exception were the method used will not incorporate the use of TI-84 Plus graphing calculator and Autograph software. To assess mental load, students were required to state their mental effort expended or used for each question they answered in assessment and achievement test based on Paas Mental Effort Rating Scale.

D. Instruments

The Paas (1992) Mental Effort Rating Scale were used to measure cognitive load by using the perceived mental effort expended in solving problems during experiments in test sheets. It has 9- point symmetrical Likert scale measurement on which subject rates their mental effort used in performing a particular learning task. It was introduced by Pass (1992) and Pass and Van Merrenboer (1994). The numerical values and labels assigned into different range from 1: very low mental effort to 9: very high mental effort.

Performance, conceptual knowledge and procedural knowledge was measured using a set of test related to the topic taught. Three questions were posed which involved students to show their understanding conceptually and procedurally. The questions were categorized as conventional problems similar to any standard examination given in the country.

IV. RESULT AND DISCUSSION

A. Effects of Graphing calculator, Autograph and Conventional strategy on Overall Performance

The means, standard deviations of the performance variable are provided in Table 1. For all statistical analysis, the 5% level of significant was used throughout the paper. The mean overall test performance for the graphing calculator group was 15.54 (SD = 3.14) meanwhile the mean overall test performance for Autograph group was 10.72 (SD = 3.47) and the mean overall test performance for conventional group was 13.03 (SD = 3.65).

The one way ANOVA test results showed that there was a significant difference in mean test performance between GC group, Autograph group and conventional group, [F (2,125) = 19.97, p<0.05]. Further, planned comparison test showed that mean overall test performance of GC group was significantly higher from those two groups followed by conventional group and Autograph group have lowest mean. This finding indicated that the GC strategy group had performed better in test phase than the conventional group and Autograph.

Table 1: Comparison of overall performance

Group	N	M	SD	SE
GC	42	15.54	3.14	.48
Autograph	39	10.72	3.47	.59
Control	47	13.03	3.65	.53

B. *Effects of Graphing calculator, Autograph and Conventional strategy on Mental Effort*

Means and standard deviations of the mental load expended during problem solving of each of the test question were obtained and as stated in Table 2. The mean mental effort during learning phase for the GC group was 4.45 (SD = 1.65) and the mean mental effort during learning phase for Autograph group was 4.10 (SD = 2.04) meanwhile the mean mental effort during learning phase for control group was 3.79 (SD = 1.96). The one way ANOVA test results showed that there was no significant difference in mean mental effort during test between GC group and conventional group, (F (2, 77) =.920, p>0.05). However, comparison of the mental effort showed that mean mental effort during learning phase of GC group was lower from those of conventional group.

In addition, it was also found that the Autograph group have highest mean mental effort during test phase (M=4.95, SD = 1.88) followed by GC group (M=4.79, SD = 1.48) meanwhile the mean mental effort during test phase for conventional group was 4.46 (SD = 1.48). The one way ANOVA test results showed that there was no significant difference in mean mental effort during test phase between GC group and conventional group, (F (2,98)= .709, p>0.05). Further, comparison test showed that mean mental effort during test phase of GC group was lower than those of the Autograph group. This findings indicated that the GC strategy group had benefited from the learning sessions hence their mental effort was lower compared to the Autograph group.

Table 2: Comparison of mental effort

Variables	Group	N	M	SD	SE
Mental effort (Learning phase)	GC	31	4.45	1.65	.29
	Autograph	22	4.10	2.04	.43
	Control	27	3.79	1.96	.37
Mental effort (Test phase)	GC	38	4.79	1.48	.24
	Autograph	35	4.95	1.88	.32
	Control	28	4.46	1.48	.28

C. *Comparison of 2-D Instructional Efficiency Index of Utilization of Graphing Calculator, Autograph and Conventional Strategy*

Table 3 shows results for evaluating the hypotheses 'There is significant difference in instructional efficiency index on groups using graphing calculator technology, Autograph technology and the conventional method in learning mathematics'.

The mean 2-D instructional efficiency for the GC group was .3844 (SD = .8802) and the mean 2-D instructional efficiency for control group was .1613 (SD= 1.0214) meanwhile the mean 2-D instructional efficiency for Autograph group was negative .5125 (SD = 1.2261).

The results of a one way ANOVA test showed that there was significant difference on mean 2-D instructional efficiency index (F (2, 98) = 7.047, p<0.05) between the GC group, Autograph group and the conventional group. The planned comparison test on mean 2-D instructional condition efficiency index showed that the mean for GC group was significantly higher than conventional group followed by Autograph group. This suggests that learning mathematics by integrating the use of GC was more efficient than using conventional strategy and Autograph mode of learning.

Table 3: Comparison on instructional efficiency

Variables	Group	N	M	SD	SE
2-D instructional efficiency	GC	38	.3844	.8802	.1428
	Autograph	35	-.5125	1.2261	.2072
	Control	28	.1613	1.0214	.1930

D. *Effects of Graphing calculator, Autograph and Conventional strategy on Other Performance Variables*

As can be seen from Table 4, the GC group (M=6.98, SD=.154) has a highest mean for the number of problem solved followed by Autograph group (M=6.64, SD=1.203) and the conventional group (M=6.28, SD=1.077). The one way ANOVA test showed significant differences, [F (2,125) = 6.223, p<0.05]. This implies that both groups solved more problems compared to the conventional group during solving the test problems.

The GC group (M=10.12, SD=3.06) has a highest mean for the total score of the conceptual knowledge followed by the conventional group (M=7.28, SD=3.63) and Autograph group (M=4.97, SD=3.24). Similar results were obtained from the total score of the conceptual knowledge, [F (2,125) = 24.275, p < 0.05]. This indicated that the GC, Autograph and the conventional groups were scoring differently based on the conceptual knowledge during the test phase. However, results obtained for the total score of the procedural knowledge showed no significant differences [F (2,125) = 3.034, p> 0.05].

In learning mathematics, the relationship between concepts and procedures has been studied in order to gain better understanding in learners tendencies to learn algorithms by rote without developing any understanding of what they are doing (Hiebert, 1986). According to Hiebert and Lefevre (1986), the students' development of conceptual and procedural knowledge varies throughout their school years. In elementary school, the algorithm that students learn may not necessarily be connected to conceptual knowledge. They might develop the conceptual understanding of addition and subtraction through a story problem. However, this understanding may not be linked with the symbols used in arithmetic to describe the relationship between the numbers in the story. As students progress in schools, they are expected to learn more rules for manipulating symbols. Hence findings from this analysis indicated that both conceptual and procedural knowledge provide insights into learners understanding or performance. Since the GC group performed better than the other two groups, these findings may suggest that use of GC have impact on learning of algebra.

Data analyses also indicated that there is significant difference in the total score of the test and number of error committed between GC and conventional group.

Table 4: Comparisons of selected variables

Variables	Group	N	M	SD	SE
No. of problems solved	GC	42	6.98	.154	.024
	Autograph	39	6.64	1.20	.193
	Control	47	6.28	1.08	.157
Total score of the conceptual knowledge	GC	42	10.12	3.06	.47
	Autograph	39	4.97	3.24	.52
	Control	47	7.28	3.63	.53
Total score of the procedural knowledge	GC	42	18.36	2.72	.42
	Autograph	39	16.92	3.86	.62
	Control	47	18.06	1.36	.19
Total score of the test	GC	42	28.48	4.15	.64
	Autograph	39	21.72	6.07	.97
	Control	47	25.34	3.78	.55
Number of errors committed	GC	42	.7937	.596	.092
	Autograph	39	2.2886	2.87	.460
	Control	47	1.5213	.898	.131

V. CONCLUSION

In this study, based on the 2-D instructional efficiency index calculation, utilizing graphing calculator was instructionally more efficient compared to conventional method and Autograph software. Use of GC had enhanced learning conditions with minimal extraneous cognitive load hence creating optimal learning condition.

Graphing calculators require students to apply their understanding of a concept so that it can be used effectively. There are many benefits using a handheld devices for instruction such as graphic calculator as reported by Ellington (2003). It was reported based on teachers' opinion that using handheld graphing calculator for instruction could increased time using technology, increased technology proficiency, student's motivation, collaboration and communication and individualized instruction.

Saurino et al. (1999) found that the use of graphing calculator technology provide students enjoyment to the use of technology, ease of portability and complete higher-level work with understanding. Meanwhile a study by Thiel and Alagic (2004) in three pre-calculus classes showed that students increased understanding of key concepts and ability to solve difficult problems when using graphing calculator. As they gain a deeper understanding of the material, students acquire the critical thinking and problem-solving skills they need to attain greater academic success.

A research conducted by Quesada and Maxwell (1994) found that students taught using the graphing calculator had significantly higher scores than those taught by traditional method. While Gage (2000) found that using graphics calculators had a significant effect on performance with functions and graphs for algebra students.

These findings suggested that in utilizing any technological tools, a comprehensive measures addressing issues of instructional efficiency is crucial especially when involving large scale and formal implementation of technology integration in teaching and learning. With systematic planning of instructions and good learning package, learning mathematics using graphing calculator and Autograph will give new view in mathematics teaching and learning. Therefore, this shows that dynamic software, particularly graphing calculator provide positive impact upon learners thus becoming potential tools in teaching mathematics at Malaysian secondary school level.

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