# LEARNING MATHEMATICS THROUGH UTILIZATION OF TECHNOLOGY: USE OF AUTOGRAPH TECHNOLOGY VS HANDHELD GRAPHING CALCULATOR

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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 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.
This study examined the effects of three teaching and learning modes on performance and mental effort (based on Paas Mental Effort Rating Scale, 2004). Experimental design was used for this study with students selected at random to be assign to three groups. Two experimental groups and a conventional group were formed. Group One underwent learning using Autograph and Group Two underwent learning using the 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, 4) testing using Achievement Test and the Paas Mental Effort Rating Scale. The data were analyzed using ANOVA and post-hoc analyses.

Graphing calculator condition is significantly efficient, $F(2, 98) = 11.1$, $p=.000$ compared to the conventional and Autograph condition. Conventional strategy incurs low mental effort and high performance. 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.

***Key-Words:*** - Technology-assisted learning, mental load, instructional efficiency index, graphing calculator, Autograph.

# 1 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.

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.

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).

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.

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 modelling 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 a 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).

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 see and know a lot of mathematical phenomena

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 teacher to make students attentive towards the 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 board 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.

### 1.1 Objectives

The purpose of this study is to investigate the effectiveness of using graphing calculator (TI-84 Plus) and Autograph Software in teaching and learning of mathematics on Form Four secondary school students' mathematics achievement in learning Quadratic Functions. Specifically, the objective of this study mainly is to compare the effect on students' mathematics achievement in learning of Quadratic Functions topic between graphing calculator group, Autograph group and the conventional instructional group.

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.

## 2 Methodology

### 2.1 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, 4) testing

using Achievement Test and the Paas Mental Effort Rating Scale. The data were analyzed using ANOVA and post-hoc analyses.

### 2.2 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.

### 2.3 Materials

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.

### 2.4 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 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.

## 3 Results and Discussion

### 3.1 Effect of GC, Autograph and CI on 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 performance**

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

### 3.2 Effect of GC, Autograph and CI 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 | .296 |
| | Autograph | 22 | 4.10 | 2.04 | .435 |
| | Control | 27 | 3.79 | 1.96 | .378 |
| 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 |

### 3.3 Effect of GC, Autograph and CI on Students' 2-D Instructional Efficiency

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 -.5125 (SD = 1.2261). The results of an 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 by integrating the use of GC was more efficient than using conventional strategy and Autograph group.

**Table 3: Comparison on instructional efficiency index**

| 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 |

### 3.4 Effect of GC, Autograph and CI on Procedural and Conceptual Knowledge

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].

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 problem 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 |

## 4 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. 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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