USING GRAPHIC CALCULATOR IN TEACHING AND LEARNING MATHEMATICS: EFFECTS ON STUDENTS’ ACHIEVEMENT AND META-COGNITIVE SKILLS

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Abstract

There has been a steady increase in interest in using hand-held technologies, in particular graphics calculators, by mathematics educators, curriculum developers and teachers. The choice of graphic calculators is motivated mainly by the potential for them to be available to essentially all students all the time (Kissane, 2000). To date, there is a substantial body of research into the use of graphics calculators (Burill et al., 2002; Dunham, 2000; Dunham, 1994; Kastberg & Leathrum 2005; Penglase & Arnold, 1996; Ruthven, 1996). Although handheld graphing technology has been available for nearly two decades, research on the use of the technology is not robust (Burill et al., 2002). Its use in secondary classrooms is not well understood, universally accepted, nor well-documented. In Malaysia, research on the usage of graphics calculators is still in its infancy and therefore its use has yet to be explored. Thus, there is a need to further research in this area especially in the context of teaching mathematics at the Malaysian secondary school level. This study employs a quasi-experimental design using two intact groups of form four secondary school students. The main objective of the study is to investigate the effects of using graphics calculator on form four secondary school students’ mathematics achievement and meta-cognitive skills in the learning area of relation and function. Students’ views about their experiences using graphic calculators in the learning of mathematics, the benefits of using graphic calculators in the learning of mathematics and the difficulties caused by using graphics calculators in practice were also sought. Preliminary findings of the study have provided pedagogical impact of the use of graphics calculator technology as a tool in teaching and learning of mathematics in Malaysia.

Keywords: Hand-held technology, graphic calculator

Introduction

Technology explosion has inspires various methodologies for the purpose of teaching and learning effectively in mathematics. One of the emphasized in Integrated Curriculum for Malaysian Secondary Schools is to use modern technology in teaching and learning of mathematics. Teachers are encouraged to employ latest technology to help students understand mathematical concepts in depth, meaningfully and precisely and enable them to explore mathematical ideas (Ministry of Education Malaysia, 2005). The significance of using technology in studying mathematics which supports the aim of Integrated Curriculum for Secondary Schools is captured in “The Technology Principle” as stated in Principles and Standards for School Mathematics, “Technology is essential in teaching and learning mathematics, it influences the mathematics that is taught and enhances students’ learning” (National Council for Teachers of Mathematics, 2000, p.24]. Thus, in parallel with the growth of technological, educators are responsible to design and develop mathematics instructional methods and strategies that employ the latest technology which could enhance students’ mathematical power.

There are many kinds of technology that are considered relevant to schools mathematics these days. These range from very powerful computer system, such as Mathematica, Maple, and MathLab to much less powerful technologies such as paper and pencil. Among those, there has been a steady increase in interest in using hand-held technologies, in particular...
graphics calculators, by mathematics educators and curriculum developers and teachers. The choice of graphic calculators is motivated mainly by the potential for them to be available to essentially all students all of the time (Kissane, 2000). In fact, graphic calculators are purpose built hand-held battery powered mathematics computers that are equipped with functions to draw and analyses graphs, computes the values of mathematical expression, solves equations, perform symbolic manipulation (requires CAS), performs statistical analyses, programmable, and communicates information between devices (Jones, 2003).

To date, there is a substantial body of research into the use of graphics calculators that have shown positive impact on students’ achievement (Burill et al., 2002; Dunham, 2000; Dunham, 1994; Kastberg & Leatheam 2005; Penglase & Arnold, 1996; Ruthven, 1996). However, research on the use of the technology is not robust although handheld graphing technology has been available for nearly two decades (Burill et al., 2002). Its’ use in secondary classrooms is not well understood, universally accepted, nor well-documented. In Malaysia, research on the usage of graphics calculators is still in its infancy and therefore its use has yet to be explored (Muhd. Khaireltitov Zainuddin, 2003; Noraini Idris, 2004). Thus, there is a need to further research in this area in the context of teaching mathematics at the Malaysian secondary school level.

Cognitive Load Theory
Cognitive load theory (CLT) (Sweller, 1988; 1994) is an internationally well known and widespread theory which focuses on the role of working memory in the development of instructional methods. The theory originated from the information processing theory in the 1980s and underwent substantial changes and extensions in the 1990s (Pass, Renkl & Sweller, 2003; Sweller, et al., 1998). Recently, more and more applications of CLT have begun to appear in the field of technology learning environment (van Merrienboer and Ayres, 2005; Mayer and Moreno, 2003, Pass et al., 2003).

Research within cognitive load perspective is based on the structure of information and the cognitive architecture that enables learners to process that information. Specifically, CLT emphasizes structures that involve interactions between LTM and STM or working memory which play a significant role in learning. One major assumption of the theory is that a learner’s working memory has only limited in both capacity and duration. Under some conditions, these limitations will somehow impede learning.

Cognitive load is a construct that represents the load which performing a particular task imposes on the cognitive system (Sweller, et al., 1998). CLT researchers have identified three sources of cognitive load during instruction: intrinsic, extraneous and germane cognitive load (e.g. Cooper, 1998; Pass, Renkl et al., 2003; Sweller et al., 1998). Intrinsic cognitive load is connected with the nature of the material to be learned, extraneous cognitive load has its roots in poorly designed instructional materials, whereas germane cognitive load occurs when free working memory capacity is used for deeper construction and automation of schemata. Intrinsic cognitive load cannot be reduced. However, both extraneous and germane cognitive load can be reduced.

According to CLT, learning will fail if the total cognitive load exceeds the total mental resources in working memory. With a given intrinsic cognitive load, a well-designed instruction minimizes extraneous cognitive load and optimizes germane cognitive load. This type of instructional design will promote learning efficiently, provided that the total cognitive load does not exceed the total mental resources during learning. Since little
consideration is given to the concept of CLT, that is, without any consideration or knowledge of the structure of information or cognitive architecture, many conventional instructional designs are less than effective (Pass, Renkl & Sweller, 2003). Further, many of these methods involve extraneous activities that are unrelated to the acquisition of schemas and rule automation. In addition, Bannert (2002) and Sweller et al. (1998) argue that in many cases it is the instructional design which causes an overload, since humans allocate most of their cognitive resources to working memory activities when learning. These extraneous activities will only contribute to the unnecessary extraneous cognitive load in which it can be detrimental to learning. Thus, for better learning and transfer performance is achieved, the main idea of the theory is to reduce such form of load in order to make more working memory capacity for the actual learning environment. In other words, the main premise of CLT is that instructional design should take into account the limitations of working memory.

Until five years ago, studies on CLT have found several effects that affect the effectiveness of teaching practices such as goal free effect, worked examples effect, problem completion effect, split-attention effect, redundancy effect, and modality effect. CLT was primarily used to study instructional methods intended to decrease extraneous cognitive load for novice learners. However, over the last five years, more and more CLT related studies have investigated the effects of instructional manipulations on intrinsic and germane cognitive load, and related those effects to the level of expertise of the learners (van Merrienboer & Sweller, 2005).

Recently, more and more applications of CLT have begun to appear in the field of technology learning environment (e.g., van Merrienboer and Ayres, 2005; Mayer and Moreno, 2003, Pass et al., 2003). Some researchers also have suggested that the use of calculators can reduce cognitive load when students learn to solve mathematics problems (Jones, 1996, Kaput, 1992; Pumadevi, 2004; Wheatley, 1980). Thus, in this study, it was hypothesized that the use of graphic calculators in teaching and learning of mathematics can reduce cognitive load and lead to better performance in learning.

Meta-cognition

The term “meta-cognition” is actually most often associated with John Flavell (1976, 1979). It was first introduced in the literature on metamemory by Flavell, Friedrichs, and Hoyt appeared in 1970. According to Flavell (1976, p.232),

"Meta-cognition refers to one’s knowledge concerning one’s own cognitive processes or anything related to them, e.g. the learning-relevant properties of information or data...Meta-cognition refers, among other things, to the active monitoring and consequent regulation and orchestration of those processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete [problem-solving] goal or objective.

The important basic concept of meta-cognition from the above definition of Flavell’s is the notion of thinking about one’s own thoughts. It is the ability to understand and monitor one’s own thoughts and the assumptions and implications of one’s activity. In other words, meta-cognition is referred the active control over the cognitive processes engaged in learning in which students have the ability to monitor, evaluate, and make plans for their learning.

In actuality, defining meta-cognition is not simple although the term has been part of educational psychologists for the last couples of decades. There is much debate over exactly what meta-cognition is. According to Livingston (1997), the reasons for this confusion are
the fact that there are several terms to describe the same basic phenomena (e.g. self-regulation, executive control), an aspect of that phenomena (e.g. meta-memory), and all these terms are used interchangeably in the literature. Moreover, descriptions are difficult because meta-cognition by its nature is a “fuzzy concept” (Flavell, 1987). Even though there is some dissent among scholars over the definition of meta-cognition, most agree that it can be simply defined as “being conscious of one’s mental process” (Gunning, 2005). In addition, Lee & Baylor (2006) assert that although meta-cognition and its constituent elements are defined differently depending on the researcher, “an awareness of one’s own cognitive activity” is commonly accepted as the definition of the meta-cognition.

There are several key operations in meta-cognition. According to Flavell (1979, 1987), Brown (1987), and Kuhn (2000), meta-cognition consists of both meta-cognitive knowledge and meta-cognitive experience or regulation. Meta-cognitive knowledge refers to acquired knowledge about cognitive processes. This knowledge can be used to control cognitive processes. In other words, meta-cognitive knowledge can be simply described as knowledge which is used to manage thinking processes.

Further, the meta-cognitive knowledge is separated by three parts: knowledge of person variables, task variables, and strategy variables (Flavell, 1979). Knowledge of person variables refers to general knowledge about how human beings learn and process information, as well as individual knowledge of one’s own learning processes. For instance, a student is aware that his/her study session will be more efficient if he/she works in the library rather than at home where there are many distractions. The task variables knowledge includes the knowledge about the nature of the task as well as the type of processing demands that it will place upon the individual. For example, a student is aware that it will take more time for him/her to read or comprehend a mathematics text than it would for him/her to read and comprehend a story book. Finally, knowledge about strategy variables include knowledge about both cognitive and meta-cognitive strategies, as well as conditional knowledge about where it can be used, and when and how to apply the appropriate strategies.

While Flavell (1987) focuses on meta-cognitive knowledge, Brown (1987) emphasizes on meta-cognitive experiences which involve the use of meta-cognitive strategies or meta-cognitive regulation. According to Brown, meta-cognitive strategies are the sequential processes that one uses to control cognitive activities. The strategies involve command of how one directs, plans, and monitors cognitive activity and it is to ensure that a cognitive goal has been met. These processes help to regulate and oversee learning. Stated differently, this aspect of meta-cognition consists of planning and monitoring cognitive activities, as well as checking the outcomes of those activities. For example, after reading of a section of one subtopic in a mathematics text, a student may question himself/herself about the concepts discussed in the section. His/her goal is to understand the text. A common meta-cognitive comprehension monitoring strategy is self-questioning. If he/she finds that he/she cannot answer his/her own questions, or does not understand the material studied, he/she must then determine what needs to be done to obtain the cognitive goal. He/she may decide to go back and re-read the section with the goal of being able to answer the questions that he/she had generated. Therefore, the meta-cognitive strategy such as self-questioning is used to make sure that the cognitive goal of comprehension is achieved. Based on the work of Flavell (1979, 1987) and Brown (1987), several researchers have operationally defines students’ meta-cognition as a construct consisting of several subscales. According to Pintrich and DeGroot (1990), meta-cognition consists of strategies for planning, monitoring and modifying one’s cognitions. O’Neil and Abedi (1996) and O’Neil
and Schacter (1997) also view meta-cognition as composed of planning, monitoring or self-checking, and cognitive strategies. O’Neil and Abedi (1996) assert that one is self-aware of the process in the following ways. For planning, one must have a goal either assigned or self-directed and a plan to achieve the goal. For self-checking, one needs the mechanism of self-monitoring to monitor goal achievement. Finally, for cognitive strategy, one must have a cognitive or affective strategy to monitor either domain-independent or domain-dependent intellectual activity. A few other researchers suggest that meta-cognition involves major operations such as planning, sequencing, self-checking or monitoring, self-questioning, evaluating, and revising (Garafalo & Lester, 1985; Beyer, 1988; Schraw & Dennison, 1994; Zimmerman, 1990).

As a strategy, Beyer (1988) suggests meta-cognition consists of three major operations: planning, monitoring/directing, and assessing a thinking task, where each of these operations consists of a number of subordinate procedures by which that operation is carried out. The first step is planning. It involves thinking about the overall process of solving tasks or problems. The second step is monitoring. At this stage, an individual executes the thinking plan and also consciously checks what is going on mentally to ensure executing the task as planned. He/she also avoids skipping or using incorrectly any steps or rules. Further, he/she sees if the operations being used are producing the desired results. The third major step is assessing which involves thinking about the processes employed in achieving the goal and the efficiency of the overall plan.

In this study, we’re proposed the potential effect of learning mathematics with graphic calculator in enhancing students’ meta-cognitive skills. Some previous studies showed positive impact on meta-cognition (Dunham & Dick, 1994; Farrel, 1996; Slavit, 1996; Hylton-Lindsay, 1998). For instance, Hylton-Lindsay (1998) claims that graphing calculator use enhances meta-cognition and encourages students to self-regulate thought process, and Slavit (1996) reports higher levels of discourse and an increase in analytic questions when calculators are in use.

Objectives
The main objectives of the study is to investigate the effects of using graphics calculator on form four secondary school students’ mathematics achievement and meta-cognitive awareness in the learning area of relation and function, specifically in the topic of Straight Lines. In this study, achievement was measured by the number of problems solved during the test phase, the total score of the conceptual knowledge for the test phase, the total score of the procedural knowledge for the test phase, the total score of the test phase, the number of similar problems solved during the test phase, the total scores of similar problems for the test phase, the number of transfer problems solved during the test phase, and the total scores of transfer problems for the test phase. Students’ views about their experiences using graphic calculators in the learning of mathematics, the benefits of using graphic calculators in the learning of mathematics and the difficulties caused by using graphics calculators in practice were also sought.

Methodology
The research study employed the quasi-experimental non-equivalent control group design. The sample of the study consisted of two intact classes of form four students from a secondary school in Selangor, Malaysia. According to the principal and mathematics teachers, both groups had comparable socio-economic and ethnic background, and each class was assigned with mixed ability - high, average and low. In order to control the differences in the dependent variables, the monthly test was used as a proxy pretest (Cook &
Campbell, 1979). For this study, one class was assigned to be the experimental group (21 students) and the other class was assigned to be the control group (19 students). The experimental group was guided by the instructional formats that incorporate the use of TI-83 Plus graphic calculators. The control group students were guided by the same instructional formats with one exception. It is a conventional whole-class instruction and they were not allowed to use the TI-83 Plus graphic calculator.

The instruments in this study consisted of a Straight Lines Achievement Test (SLAT), a Meta-cognitive Awareness Survey (MCAS), and a Graphic Calculator Usage Survey (GCUS). The SLAT was designed by the researcher to measure students’ understanding of the Straight Lines topic. It comprised of seven questions based on the subtopic of straight lines covered in the experiment. The time allocated to do the test is 40 minutes. The overall scores for the SLAT are 40. The MCAS was adapted from the “State Meta-cognitive Inventory” by O’Neil & Abedi (1996) to measure students’ meta-cognitive awareness in mathematical problem solving. It is a 20 items with four point Likert scale instrument, consisted of the following subscales: planning, monitoring, cognitive strategy and awareness. Based on O’Neil & Abedi (1996) studies, for the 12th graders, alpha reliability estimates and factor analysis indicated that their meta-cognitive subscales are reliable (alpha above 0.70) and uni-dimensional. The GCUS was prepared by the researcher to determine students’ of GCS group views about the graphic calculator usage in teaching and learning of mathematics. There are three open questions in the survey: (i) Explain your experience using graphic calculators in learning of Straight Lines topic, (ii) What do you think are the benefits of using graphic calculators in learning of Straight Lines topic, and (iii) What are the difficulties caused by using graphic calculators in practice.

The experiment lasted for 2 weeks with the researcher handling the two intact classes scheduled consecutively on the same day, three times a week, 40 minutes per meeting. Both groups have identical conditions in terms of the lessons structure, mathematical tasks and contact hours. As part of the preparation for the study, the first two periods were used to introduce and familiarize the experimental group students with the features and functions of the TI-83 Plus graphing calculator. At the end of the study, the SLAT and MCAS were administered to both the experimental and control groups. In addition, the experimental group was given the GCUS which requested information on students’ views of the graphic calculator usage.

Results and Discussions
(i) Students’ mathematics achievement

Table 1: Means and Standard Deviations for Experimental (graphic calculator) and Control (conventional) Groups on Monthly Test

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>Graphic Calculator</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly Test</td>
<td>N</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>59.00</td>
<td>59.26</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>10.252</td>
<td>21.189</td>
</tr>
</tbody>
</table>

Table 1 gives the means and standard deviations of the monthly test score for both graphic calculator (GC) and conventional groups. The total monthly test score is 100. The mean score for the experimental group and the control group are 59.00 and 59.26 respectively. For all statistical analyses, the 5% level of significant is used throughout the paper. The
result of the t-test indicates that there is a statistically no significant difference between the mean of monthly test score for the GC group and conventional group ($t \ (38) = -0.051$, $p > 0.05$, SE difference = 5.183). This suggested that the students’ mathematics performance for both groups in our sample does not differ significantly. Therefore, an independent samples t-test is used to compare the means of the dependent variables for both two independent groups, GC group and conventional group.

<table>
<thead>
<tr>
<th>Aspects of Achievement</th>
<th>Graphic Calculator</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of problems solved</td>
<td>Mean 2.19</td>
<td>1.53</td>
</tr>
<tr>
<td>SD</td>
<td>1.12</td>
<td>0.84</td>
</tr>
<tr>
<td>Total score of the conceptual knowledge</td>
<td>Mean 9.10</td>
<td>7.26</td>
</tr>
<tr>
<td>SD</td>
<td>3.40</td>
<td>3.46</td>
</tr>
<tr>
<td>Total score of the procedural knowledge</td>
<td>Mean 7.71</td>
<td>5.26</td>
</tr>
<tr>
<td>SD</td>
<td>2.43</td>
<td>2.56</td>
</tr>
<tr>
<td>Total score of the test</td>
<td>Mean 16.81</td>
<td>12.53</td>
</tr>
<tr>
<td>SD</td>
<td>4.76</td>
<td>4.99</td>
</tr>
<tr>
<td>No. of similar problems solved</td>
<td>Mean 1.48</td>
<td>1.26</td>
</tr>
<tr>
<td>SD</td>
<td>0.75</td>
<td>0.65</td>
</tr>
<tr>
<td>Total scores of similar problems</td>
<td>Mean 9.67</td>
<td>8.21</td>
</tr>
<tr>
<td>SD</td>
<td>2.00</td>
<td>1.96</td>
</tr>
<tr>
<td>No. of transfer problems solved</td>
<td>Mean 0.71</td>
<td>0.26</td>
</tr>
<tr>
<td>SD</td>
<td>0.85</td>
<td>0.56</td>
</tr>
<tr>
<td>Total scores of transfer problems</td>
<td>Mean 7.14</td>
<td>4.32</td>
</tr>
<tr>
<td>SD</td>
<td>5.00</td>
<td>4.22</td>
</tr>
</tbody>
</table>

The means and standard deviations of the variables under analysis are provided in Table 2. The posttest data were analyzed with independent samples t-test. As can be seen from Table 2, the GC group ($M = 2.19$) has a higher mean for the number of test problems solved than the conventional group ($M = 1.53$). However, the t-test showed that the differences in the means were not significant, $t(38) = 2.098$, SE difference = 0.317. This implies that both groups performed more or less equally on the test problems.

Similar results were obtained for the other variables such as the total score of the procedural knowledge ($t(38) = 1.686$, SE difference = 1.087, $P > 0.05$), the number of similar problems solved ($t(38) = 0.953$, SE difference = 0.223, $P > 0.05$), the number of transfer problems solved ($t(38) = 1.965$, SE difference = 0.230, $P > 0.05$), and the total score of transfer problems ($t(38) = 1.921$, SE difference = 1.471, $P > 0.05$). This indicates that the GC and the conventional groups were scoring more or less the same for the procedural knowledge and the transfer problems, and also both groups were successfully solved more or less the same number of similar and transfer problems during the test phase.

For the total score of the procedural knowledge ($t(38) = 3.107$, SE difference = 0.789, $P < 0.05$), the total score of the test phase ($t(38) = 2.777$, SE difference = 1.543, $P < 0.05$), and the total scores of similar problems ($t(38) = 2.316$, SE difference = 0.629, $P < 0.05$), the data analyses indicated a significant difference between the GC and conventional groups. The GC group has higher means for all the three variables ($M = 7.71, 16.81,$ and $9.67$ respectively) than the conventional group ($M = 5.26, 12.53,$ and $8.21$ respectively). This indicates that the GC group was scoring better for the conceptual knowledge, test questions phase, and similar problems than the conventional group.

Overall, the results of the t-test analyses indicate that both groups were quite similar in performing the test problems, scoring the procedural knowledge and the transfer problems,
and solving the number of similar and transfer problem during the test phase. However, the GC group has performed better than the conventional group on all the total scores such as the conceptual knowledge, the test questions, and similar problems accept the score for the transfer problems. This result might due to the short-term use of the GC was insufficient in demonstrating the transfer problems skills in the test without the aid of GC. Dick [15] asserts that the time available for students to concentrate on analyzing problems and solution is doubled.

“With powerful numeric, graphical, and symbolic computational tools in hand, the students can see the ‘carry out the plan’ stage of problem solving as the least daunting step. Students appreciate more the relative importance of heuristics processes, mathematical modeling, and the interpretation of results.” [15, p. 152]

It is also important to note that the use of GC do assist in increasing conceptual knowledge score without adversely affecting procedural knowledge score which is in line with Barton’s report (Connors & Snook, 2001). The findings of this study also supported the previous syntheses of the literature and meta-analyses on the effects of using GC in teaching and learning of mathematics indicated that overall, handheld graphing technology can be an important factor in helping students develop better understanding of mathematical concept, score higher on performance measures, and achieve a higher level of mathematical problem solving skills (e.g. (Burill et al., 2002; Connors & Snook, 2001, Dunham, 2000; Dunham, 1994; Kastberg & Leatheam 2005).

(ii) Students’ Meta-cognitive Skills

Means and standard deviations of the variable under analysis are provided in Table 3. The posttest mean for the experimental group was 2.94 (SD = 0.366) compared to the control group mean of 3.15 (SD = 0.277). Further, a t-test analysis performed on the meta-cognitive skills variable showed that there were no significant differences among the experimental and control groups (t(36) = -1.922, SE difference = 0.107, p > 0.05).

Table 3: Means and Standard Deviations for Experimental and Control Groups on Posttest MCSS

<table>
<thead>
<tr>
<th>Test</th>
<th>Group</th>
<th>Experimental</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metacognitive Skills Survey</td>
<td>N</td>
<td>21</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>2.94</td>
<td>3.15</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation</td>
<td>0.366</td>
<td>0.277</td>
</tr>
</tbody>
</table>

The result of the analysis of the meta-cognitive awareness indicated that using GC in teaching and learning of mathematics did not significantly improve students’ meta-cognitive awareness. This result contradicted some previous studies (Gage, 2002; Hylton-Lindsay, 1998; Keller and Russel, 1997). Gage (2002) found that the GC did indeed form a focus for reflective discussion which led to cognitive change. This might imply that students should work in pairs to encourage reflective discussion and hence shaping the higher mental processes of the students such as their meta-cognitive awareness. Hylton-Lindsay (1998) analyzed of students’ scores indicates that the GC enhanced the meta-cognitive aspect of students’ performance, particularly students’ thought processes and their ability to self-regulate. For Keller & Russel (1997), students using CAS technology were more able to concentrate on developing their conceptual understanding of calculus and development of meta-cognitive behaviors which support problem solving. This result might due to the questions used in the test did not pose a high enough meta-cognitive awareness, the students did not capable of demonstrating these skills in the
test without the aid of GC, and that the short-term use of the GC was insufficient in establishing the meta-cognitive awareness. It is also might due to the MCAS instrument used in the study to measure general meta-cognitive awareness is not suitable to show the effect of the GC intervention on meta-cognitive awareness. These assertions merit further consideration.

**Students’ GCUS Summary**

(a) Students’ views about their experiences using graphic calculators in learning of Straight Lines topic

Overall, students’ experience using graphic calculator can be divided into two categories: positive experience and negative experience. Most of the students (26 students - 92.9%) expressed their experience using graphic calculator in learning of Straight Lines topic with positive affection. The commonly used words to describe their feelings are “interesting”, “exciting”, “good”, and “impressive”. Only two students (7.1%) feel that they have negative experience. There were not completely convinced that graphic calculator is a useful tool in learning mathematics.

(b) Students’ views on the benefits of using graphic calculators in the learning of Straight Lines topic

The overall remark made by the respondents was positive and encouraging. There were four categories found. Firstly, 12 students (42.9%) suggest that the GC usage helps them to understand the straight lines concept better. They claimed that GC usage enhances students’ performance, helps in determining the value of gradient easier, draws graph easier, helps in solving problems, and provides information and various graphing capabilities. Secondly, 12 students (42.9%) agree that the GC usage helps them to get the answer faster and accurate. In addition, they can save time and papers when doing problem solving. Thirdly, 3 students (10.7%) feel that the GC usage stimulates their interest in learning the Straight Lines topic. Finally, one student (3.6%) notes that the GC usage provides opportunity in using new technology.

(c) Students’ views on the difficulties caused by using graphic calculators in practice.

Out of 28 students that respond to this question, four students (14.3%) feel that they are not having difficulties, three students (10.7%) did not answer the question, and 21 students (75%) agree that they are having difficulties. The difficulties caused by using GC in practice can be summarized due to the first time that GC were introduced and were used in learning mathematics. Therefore, they don’t have enough time to learn the different function keys of the GC. Majority of the students also claimed that the keys on GC are difficult to remember, many steps to follow in the instructions of using GC, and they have to be very cautious in using the cursor to trace the coordinates on the straight line.

Overall, even though a few students are having difficulties due to the first time that GC were introduced and were used in learning mathematics, we are very encouraged with the survey findings. Majority of the students responded positively and favorably towards using GC in teaching and learning of Straight Lines topic. This result coincides with many other studies such as Hennessey et al. (2001), Kor Liew Kee & Lim Chap Sam (2003), and Quesada (2003), Smith and Shortberger (1997). For example, from the cognitive domain Smith and Shortberger (1997) found that “more than 70% of the students specifically identified the calculator as helping them to “understand more fully” or to see certain ideas “better” (p.
The survey and the case study of Hennesey et al. (2001) support the conclusion that GCs facilitated graphing using visual representation, by making the process less time-consuming, and encouraging translation. An interesting result from the study by Kor Liew Kee & Lim Chap Sam (2003) is that students “looked upon themselves as technological-able and valued themselves as more marketable in the society” (p. 23). However, a few studies also demonstrate that there are some difficulties associated with the use of GC such as using an incorrect syntax for formula entry leading to incorrect answer (Hong et al., 2000) and the top-down character of a CAS, its black-box style and its idiosyncrasies of syntax produced obstacles during the performance of instrumentation schemes and during the interpretation of the results (Drijvers, 2000).

Conclusion

The results from the experiment provided some evidence that the use of GC can be helpful in improving students’ achievement in mathematics. Specifically, this study showed that the treatment group outperformed the control group in students’ conceptual knowledge score, test phase score and similar problems score of a Straight Lines topic. A number of students also had difficulties in using GCs due to the first time the GC were introduced and were used in learning mathematics. The study also showed that using GC in teaching and learning of mathematics did not significantly improve students’ meta-cognitive awareness.

It is also important to note that simply having access to technology does not insure it will be used to enhance learning of mathematics (Connors & Snook, 2000). Moreover, Dunham and Dick (1994) also noted that the mere presence of graphing technology may not account for the positive results that have been found in studies. Several studies also suggested that the impact of the technology in the secondary classroom might depend as much on the ways in which the technology is used to mediate mathematics in the classroom [e.g. Burrill et al., 2002; Hennessey, 2000]. In general, more research is uncovering the specific areas of mathematics that are helped by graphic calculator use and those areas that are hindered by the technology. It is not really clear what causes the improvement in scores when the GC is used. Several factors may be considered. Thus, the findings of the study will be used to help the researcher to emphasize the need to highlight certain considerations when designing future experiments.

References

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