GRAPHING CALCULATOR STRATEGY IN TEACHING AND LEARNING OF MATHEMATICS: EFFECTS ON CONCEPTUAL AND PROCEDURAL KNOWLEDGE PERFORMANCE AND INSTRUCTIONAL EFFICIENCY

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ABSTRACT

Two series of quasi-experimental study with non-equivalent control group post-test only design were conducted to investigate the effects of using graphic calculators in mathematics teaching and learning specifically in the Straight Line topic, on Form Four(16 year-old) Malaysian secondary school students' conceptual and procedural knowledge performance and 3-D instructional efficiency index. Experiment in Phase I was conducted to provide an initial indicator of the effectiveness of graphic calculator strategy on students' performance. Experiment for Phase II was further carried out incorporating measures of mathematical performance, namely the conceptual and procedural knowledge performance and measures of instructional efficiency. There were two instruments used in this study namely, the Straight Lines Achievement Test and the Mental Effort Rating Scales. The data were analysed using independent t-test and planned comparison test. The results of this study showed that the graphic calculator strategy group had better conceptual knowledge performance as compared to conventional instruction strategy group and most important they did not lose procedural knowledge performance. In addition, the study also showed that the graphic calculator instruction increased the 3-dimensional instructional efficiency index in learning of Straight Lines topic. These findings indicated that the graphic calculator instruction is superior in comparison to the conventional instruction, hence implying that it was more efficient instructionally than the conventional instruction strategy.

1. Introduction

Concept building and skills acquisition as well as the inculcation of good and positive values are the main focus in teaching and learning processes for Malaysian mathematics [1]. There are also other elements that have been taken into account and infused into the teaching and learning for mathematics as stated in the Malaysian Mathematics Curriculum Specifications, namely, (i) problem solving, (ii) mathematical communication, (iii) making connection, (iv) reasoning, and (v) the use of technology.

Among those elements, the use of technology in teaching and learning of mathematics has consistently been one of the major emphases in Malaysian Integrated Curriculum for Secondary School Mathematics. Technology explosion has inspired various methodologies for the purpose of effective teaching and learning in mathematics. Teachers are encouraged to use the latest technology to help students understand mathematical concepts in depth, to enable them to explore mathematical ideas [1]. This emphasis is congruent with the NCTM's Technological Principle which states that, "*Technology is essential in teaching and learning mathematics, it influences the mathematics that is taught and enhances students' learning*" [2, p. 24].

The emphasis on integrating technology in the teaching and learning of mathematics is parallel with the aim of the Malaysian mathematics curriculum: to develop individuals that are able to face challenges in everyday life that arise due to the advancement of science and technology [1].

However, technology does not replace the need for all students to learn and master the basic mathematical skills. Without the use of technologies such as the calculators or other electronic tools, students should be able to add, subtract, multiply and divide efficiently. The mathematic curriculum therefore requires the use of technology to focus on the acquisition of mathematical concepts and knowledge rather than merely doing calculation.

2. Conceptual versus Procedural Knowledge

Conceptual and procedural are two types of knowledge that are assumed to be distinct yet closely related. Whether procedural knowledge necessarily comes before conceptual knowledge is not an issue. Both types of knowledge may develop along parallel tracks. Hiebert & Lefevre [3] explain that procedural knowledge is possible without conceptual knowledge, but conceptual knowledge includes knowledge of the language of mathematics and mathematical procedures. In addition, they suggest that this is true because "…procedures translate conceptual knowledge into something observable. Without procedures to access and act on the knowledge, we would know it was there…" (p. 9). From a mathematical expert's point of view, procedures always depend upon principles represented conceptually [4]. It means that all mathematical procedures are potentially associated with connected networks of information. Thus, if concepts and procedures are not connected, students' understanding of mathematical concepts will not be complete.

Certain benefits accrue when conceptual and procedural knowledge are linked. [3. p. 11] explain that: If conceptual knowledge is linked to procedures, it can: (a) enhance problem representations and simplify procedural demands; (b) monitor procedure selection and execution; and (c) promote transfer and reduce the number of procedures required". Therefore, linking conceptual and procedural knowledge is important in learning process; it helps students to develop a deeper understanding of concepts and strengthens the procedural used.

Unfortunately, most school mathematics curricula are overly concerned with developing procedural knowledge in the form of speed and accuracy in using computational algorithms rather than the development of higher order thought processes ([5], [6]). If we agree that a main goal of mathematics education is to develop both procedural knowledge and conceptual knowledge and make links between them, a very important question regarding mathematics education in the 21st century is "*how different technologies affect the relation between procedural and conceptual knowledge*" [7, p.549]. Thus, this study will look at technologies such as graphic calculators in teaching and learning of mathematics on students' performance variables such as conceptual and procedural knowledge performance and the instructional efficiency index.

3. The Use of Graphic Calculators

As in many other countries, schools in Malaysia are equipped with computers in computer laboratories but not all students could have regular access to them. Those computers are used for all subjects taught in school, thus reducing the accessibility of computers for mathematics lesson. The use of technological props in mathematics teaching and learning namely the graphic calculators may benefit students and hence could materialise the Malaysian national agenda of introducing technology in the classroom. However, many teachers and parents believe that using technology may deprive students from employing their brains to perform computations and algebraic manipulations. There is a belief that calculators may cause students to lose basic mathematical skills and understanding needed in advanced mathematics [8].

In Malaysia, calculators were strictly prohibited at both the primary and lower secondary levels before the year 2002. However, in 2002, usage of calculator was introduced for Form Two and Three students (14-15 year-old) in lower secondary mathematics curriculum ([9], [10], [11]). Currently, the usage of calculators is still prohibited in the primary grades while the usage of scientific calculators is prohibited in Form One. The latest reform in the Malaysian Secondary School Integrated Mathematics Curriculum calls for the need to integrate information technology in teaching and learning of mathematics. In response to this call, mathematics teachers and students are now encouraged to use scientific and graphic calculators in the upper secondary mathematics classroom. Moreover, currently, scientific calculators are already allowed to be used at the Malaysian Certificate of Education examination level.

The use of graphic calculators in teaching and learning enable various kinds of guided explorations to be undertaken. For example, students can investigate the effects of changing parameters of a function on the shape of its graph. They can also explore the relationships between gradients of pairs of lines and the lines themselves. These activities would have been too difficult to attempt without technology. Exploratory activity in mathematics may facilitate an active approach to learning as opposed to a passive approach where students just sit back passively listening to the teacher. This creates an enthusiastic learning environment. This clearly shows the application of constructivist learning environment.

Graphic calculators also offer a method of performing computations and algebraic manipulations that is more efficient and precise than paper-and-pencil method alone. Examples include finding the solutions of simultaneous equations or determine the equation of a straight line that is passing through two points. The mathematical concepts underpinning those procedures are rich and important for understanding. However, students often seem to put more effort in calculation and correspondingly less to making sense of the problems. Both attention to concepts and skill would be desirable in mathematics learning.

Rather than just development of mechanical and computational skills, graphic calculators also allow for cultivation of analytical adeptness and proficiency in complex thought process. Problems representing real-world situation and data with complicated numbers can also be addressed. This would offer new opportunities for students to encounter mathematical ideas not in the curriculum at present. With appropriate use of graphic calculator, students can avoid time-consuming, tedious procedures and devote a great deal of time concentrating on understanding concepts, developing higher order thinking skills, and learning relevant applications. In addition to paper-and-pencil, mental and estimation skills, the graphic calculator assists student to execute the procedures necessary to understand and apply mathematics.

Jones [12] argued that when students work with graphic calculator, they have potential to form an intelligent partnership, as graphic calculator can undertake significant cognitive processing on behalf of the user. This argument is in line with the distributed cognition and cognitive load theories. Distribution of cognition such that the larger part of cognitive process is taken over by the graphic calculator allows learners to focus more on problem solving. From the cognitive load perspective, the focus of learning is to acquire problem solving schema rather than to acquire automation of mental arithmetic per se that distracts the real aim of problem solving. The distracting activities might exhaust learners' mental resources such that these activities will impose extraneous cognitive load and hence will be detrimental for learning. Therefore, instructional strategy that integrates the use of graphic calculator seems logical to reduce extraneous and increase germane cognitive load. This is because, as a result of distribution of cognition, graphic calculator offloads part of the cognitive process that reduces extraneous cognitive load, and this allows the learners to focus on more processing tool relevant for learning. The tool will help free the mental resources to enable them to acquire the necessary schemas and automation, or in other words the strategy simultaneously increases the germane cognitive load, hence increases the instructional efficiency index.

4. Purpose and Objective of the Study

The purpose of this study is to investigate the effects of integrating the use of graphic calculator in mathematics teaching and learning on performance for Form Four secondary school students when learning Straight Lines topic. Thus, two types of instructional strategy that is the graphic calculator strategy and the conventional instruction strategy were compared on performance and instructional efficiency. A progressive series of two experiments was conducted in this study. Phase I was a preliminary study. This phase sought to provide indicators of the effectiveness of graphic calculator strategy on students' performance. Phase II of the study was further carried out incorporating measurements of instructional efficiency.

5. Methodology

5.1 Design

For both phases, the quasi-experimental non-equivalent control-group post-test only design [13] was employed. Due to several reasons mentioned previously, assigning subjects randomly to groups in practice is not possible. However, random assignment of classes can be done in which it controls sample biased problem of the group. In this study of quasi-experimental, the classes involved were randomly assigned to the experimental and the control groups.

The most obvious flaw in this design is the absence of pre-test, which leads to the possibility that any post-test differences between the groups can be attributed either to the treatment effect or to the selection differences between the different groups. According to [13], one approach to make the groups comparable is to choose homogeneous samples by selecting subjects who vary little in their personal characteristics or attributes. For both phases, several steps were taken to ensure the group's initial equivalence: (i) classes that were involved were based on school reports and discussions with the school's principal and mathematics teachers in which both groups, the control and experimental had comparable socio-economic and ethnic background, and each class was assigned with mixed ability - high, average and low, (ii) the major extraneous variable that might influence the outcome in this study will be the students' mathematics ability. Thus, results from the previous monthly test were further analysed to ascertain that the students in both groups were of similar mathematics ability, and (iii) students' profile information such as students' mathematics PMR achievement (national examination taken by all Form 3 (15-year old) students in Malaysia), whether students attended mathematics tuition classes or not, and whether students attended graphic calculator courses or not were obtained for both experimental and control groups.

In this study, the independent variable that was being manipulated was the instructional strategy (graphic calculator strategy and conventional instruction strategy). The dependent variables in this study were the measures of performance and instructional efficiency index. The performance measured together with the cognitive load (mental effort) served as an indicator of the instructional efficiency of an instructional strategy.

5.2 Population and Sample

The target population for this study was Form Four (11^{th} grade level or 16 year-old) students in National secondary schools in Malaysia whilst the accessible population was Form Four students from one selected school in Selangor and Malacca. Each phase was carried out within one particular school only. A total of 40 students took part in Phase I such that there were 20 students in the GC strategy group and there were 19 students in the CI strategy group. A total of 65 students took part in second phase of the study. The GC strategy group consisted of 33 students while the CI strategy group consisted of 32 students.

5.3 Materials

The instructional materials for Phase I consisted of six sets of lesson plan, whilst for Phases II consisted of fifteen sets of lesson plan of teaching and learning of Straight Lines topic. The Straight Lines topic includes subtopics such as understand the concept of gradient of a straight line, understand the concept of gradient of a straight line in the Cartesian coordinates, understand the concepts of intercepts, understand and use equation of a straight line, and understand and use the concept of parallel lines. The main feature of the acquisition phase for the GC strategy group was that students used “balanced approach” in learning of Straight Lines topic. Wait & Demana [14] illustrated that the “balanced approach” is an appropriate use of paper-and-pencil and calculator techniques on regular basis (p.6). Specifically, the TI 83 Plus Graphing Calculator was used in this study. The following strategies were implemented in teaching and learning of the topic:

i. Solves analytically using traditional paper and pencil algebraic methods, and then supports the results using a graphic calculator.
ii. Solves using a graphic calculator, and then confirms analytically the result using traditional paper and pencil algebraic methods.
iii. Solves using graphic calculator when appropriate since traditional analytic paper and pencil methods are tedious and/or time consuming or there is simply no other way.
iv. Use manipulative and paper-and pencil techniques during initial concept development and use graphic calculator in the “extension” and “generalizing” phase.
v. Approach and solve problems numerically using tables on graphic calculator.
vi. Model, simulate and solve problem situations using graphic calculator and then confirm, when possible using analytic algebraic paper and pencil methods.

The CI strategy group was also guided by the same instructional format with conventional whole-class instruction without incorporating the use of graphic calculator. The following are the activities which were used by the researcher in the classroom:

i. Teacher explains the mathematical concepts using only the blackboard.
ii. Teacher explains on how to solve mathematical problems related to the concepts explained.
iii. Students are given mathematical problems to be solved individually.
iv. Teacher handles discussion of problem solving.
v. Teacher gives the conclusion of the lesson.

For all phases, the procedures for the experiment were the same. The pre-experiment procedures were carried out before each experiment which includes a general briefing about the study and three periods of introducing the graphing calculator usage for the experimental group and collecting students’ profiles information.

5.4 Instruments

There were two instruments used in this study namely the Straight Lines Achievement Test (SLAT) and the Mental Effort Rating Scale (MERS) [15]. The SLAT had two variations because these instruments were modified based on the results of preceding phases. For Phase I, the SLAT comprised of seven questions based on the Straight Lines topic covered in the experiment. The scores for each problem solution were allotted one mark for each correct step in the solution. Problem solution for questions one to seven had 3, 4, 5, 5, 5, 11 and 7 steps respectively as indicated in the marking scheme. Thus, the overall performance test for the SLAT ranged between 0 and 40. In addition, the researcher also classified students' solution as either acquisitions of conceptual or procedural knowledge performance. The conceptual knowledge performance refers to students' ability to interpret, explain, and to apply mathematical concepts in Straight Lines topic to a variety of situations and translate between verbal statements and mathematical expressions, whereas the procedural knowledge performance refers to students' ability to solve mathematical problems in Straight Lines topic which requires algorithm-based method. Hence, the total scores for conceptual and procedural knowledge performance were 18 and 22 respectively. The reliability index using Cronbach's alpha coefficient was 0.57. This index was not an acceptable level based on [16] cut-off point of 0.70. However, according to [17], a lower reliability coefficient (in the range of 0.50 to 0.60) might be acceptable if the measurement results are to be used in making decisions about a group. Thus, the reliability of SLAT for this phase was reasonably acceptable.

For Phase II, the SLAT comprised of 12 questions and the total test score was 60. The time allocated to do the test was one hour and 30 minutes. Similarly, the scores for each problem solution were allotted one mark for each correct step in the solution. Problem solution for questions one to twelve had 4, 5, 4, 1, 5, 4, 2, 5, 9, 7, 8, and 6 steps respectively as indicated in the marking scheme. Thus, the overall performance test for the SLAT ranged between 0 and 60. Students' solution was also classified as either acquisition of conceptual or procedural knowledge performance. Hence, the total scores for conceptual and procedural knowledge performance were 34 and 26 respectively. The computed index of reliability, α, for the SLAT was determined to be 0.68. The computed index of reliability for the SLAT was determined to be 0.68. Based on [16] scale, the reliability of the SLAT was not at an acceptable level. However, a lower reliability coefficient in the range of 0.50 to 0.60 might be acceptable according to [17]. In addition, [18] suggested that the reliability coefficient as low as 0.50 can be accepted if the test was to be used to make decisions about a group. Thus, the reliability of SLAT for Phase II was considered sufficiently acceptable.

The MERS was used to measure cognitive load by recording the perceived mental effort expended in solving a problem in experiment Phases II. It was a 9-point symmetrical Likert scale measurement on which subject rates their mental effort used in performing a particular learning task. It was introduced by [15] and [19]. The numerical values and labels assigned to the categories ranged from very, very low mental effort (1) to very, very high mental effort (9). For each question in SLAT of Phases II and III, the MERS was printed at the end of the test paper. After each problem, students were required to indicate the amount of mental effort invested for that particular question by responding to the nine-point symmetrical scale. The computed indices of reliability for MERS in both phases were 0.87. These indicated that the instrument was acceptably reliable and suggested that it was capable of measuring students' cognitive load. There were two kinds of subjective ratings of mental effort taken during the experiments in Phases II, the subjective ratings of mental effort were taken during learning in evaluation phase for each lesson. Secondly, it was taken during test phase. The mental effort per problem was obtained by dividing the perceived mental effort by the total number of problems attempted for each evaluation phase during learning and that of the test phase.

6. Results

The exploratory data analysis was conducted for all the data collected in all phases. Students' performance was measured by the overall test performance, conceptual and procedural knowledge performance. The overall test performance in this study refers to students' overall achievement based on the SLAT score. The 3-dimensional (3-D) instructional condition efficiency indices were also calculated using [20] procedure and were taken into the analyses as dependent variables. The 3-D efficiency index was computed using the formula, $E = (P - E_L - E_T)/\sqrt{3}$, where P is z score for performance, E_L is z score for learning effort and E_T is z score for the test effort [20]. The greatest instructional condition efficiency would be occurred when the performance score was the greatest and the effort scores were the least. On the other hand, the worst instructional efficiency condition would occur when the performance score was the least and the effort scores were the greatest.

For both phases, the comparative analyses using independent samples t-tests were used to explained differences exist in means of dependent variables between GC strategy and CI strategy groups. Further, the planned comparisons were conducted in order to ascertain that the means of dependent variables for GC strategy group are significantly higher from those of CI instruction strategy groups.

6.1 Phase I - Effect of GC Strategy and CI Strategy on Performance, Conceptual and Procedural Knowledge Performance

The means, standard deviations of the variables under analysis and the results of the independent samples t-test are provided in Table 1. As can be seen from Table 1, the mean overall test performance of GC strategy group was 16.81 (SD=4.76) and mean overall test performance for CI strategy group was 12.53(SD=4.99). Independent samples t-test results showed that there was a significant difference in mean test performance between GC strategy group and the CI strategy group, t(38)=2.78, p<0.05. The magnitude of the differences in the means was large based on [21] with eta squared =0.17. Further, planned comparison test showed that mean overall test performance of GC strategy group was significantly higher from those of CI strategy group, F(1, 38)= 7.71, p<0.05. This finding indicated that the GC strategy group had performed better for test phase than the CI strategy group.

Table 1. Means, standard deviations, independent sample t-test and planned comparison for overall test performance, conceptual and procedural knowledge performance in Phase I

	Group	n	M	SD	SEM	t	df	p
Overall test performance	GC strategy	21	16.81	4.76	1.04	2.78	38	0.008
	CI strategy	19	12.53	4.99	1.15			
Conceptual knowledge performance	GC strategy	21	7.71	2.43	0.53	3.11	38	0.004
	CI strategy	19	5.26	2.56	0.59			
Procedural knowledge performance	GC strategy	21	9.10	3.40	0.74	1.69	38	0.100
	CI strategy	19	7.26	3.46	0.79			

The total score for conceptual knowledge performance was 18. The mean conceptual knowledge performance of the GC strategy group was 7.71 (SD=2.43) while the mean conceptual knowledge performance of the CI strategy group was 5.26 (SD=2.56). An independent t-test showed that the difference in the means were significant, t(38)=3.11, $p<0.05$. Hence, there was a significant difference in the mean conceptual knowledge performance during the test phase in the learning of the Straight Lines topic between the GC strategy group and the CI strategy group. The magnitude of the differences in means was large based on [21] with eta squared =0.20. Further, planned comparison test showed that the mean conceptual knowledge performance of the GC strategy group was significantly higher from those of the CI strategy group, F(1,38)= 9.65, $p<0.05$. This finding suggested that using the graphic calculator enhanced performance on conceptual knowledge as compared to the conventional teaching.

The total score for procedural knowledge performance was 22. The mean procedural knowledge performance of the GC strategy group was 9.10 (SD=3.40) while the mean procedural knowledge performance of the CI strategy group was 7.26 (SD=3.46). An independent t-test showed that the difference in the means was not significant, t(38)=1.69, $p>0.05$. The results showed that there was no significant difference in the mean procedural knowledge performance during the test phase in the learning of the Straight Lines topic between the GC strategy group and the CI strategy group. The magnitude of the differences in means was moderate based on [21] with eta squared =0.07. Further, planned comparison test showed that the mean performance on procedural knowledge of the GC strategy group was not significantly higher than those of the control group, F(1,38)=2.86, $p>0.05$. This finding confirmed that there are no differential effects on procedural knowledge performance between the GC strategy and the CI strategy groups.

6.2 Phase II - Effect of GC Strategy and CI Strategy on Performance, Conceptual and Procedural Knowledge Performance

The means, standard deviations of the variables under analysis and the results of the independent samples t-test are provided in Table 2. As can be seen from Table 4, mean overall test performance of the GC strategy group was 24.21 (SD=9.69) and mean overall test performance of CI strategy group was 17.75 (SD=10.54). Independent samples t-test results showed that there was a significant difference in mean overall test performance between GC strategy group and the CI strategy group, t(63)=2.57, $p<0.05$. The magnitude of the differences in the means was moderate based on [21] using eta squared =.64. Planned comparison test showed that the mean test performance of GC strategy group was significantly higher from those of CI strategy group, F(1, 63)= 6.60, $p<0.05$. This suggested that the GC strategy group had performed significantly better for the test phase than the CI strategy group.

Table 2. Means, standard deviations, independent sample t-test and planned comparison for overall test performance, conceptual and procedural knowledge performance in Phase II

	Group	n	M	SD	SEM	t	df	p
Overall test performance	GC strategy	33	24.21	9.69	1.69	2.57	63	0.012
	CI strategy	32	17.75	10.54	1.86			
Conceptual knowledge performance	GC strategy	33	15.70	4.81	0.84	4.30	57.18	0.000
	CI strategy	32	9.59	6.48	1.15			
Procedural knowledge performance	GC strategy	33	8.18	5.58	0.97	0.02	63	0.984
	CI strategy	32	8.16	4.59	0.81			

The total score for conceptual knowledge performance was 34. The mean conceptual knowledge performance of GC strategy group was 15.70 (SD=4.81) while that of CI strategy group was 9.59

(SD=6.48). It is to be noted that Levene's test indicated that the assumption for equal variance has been violated, F= 4.51, $p<0.05$. Therefore the reading for the output for the independent t-test is based on the reading for equal variance not assumed. An independent t-test showed the difference in means was significant, $t(57.18)=4.30$, $p<0.05$. The results showed that there was a significant difference in the mean conceptual knowledge performance in the learning of the Straight Lines topic between the GC strategy group and the CI strategy group. The effect size was 0.23 using eta squared value which was large based on [21]. Further, planned comparison test showed that the mean conceptual knowledge performance of the GC strategy group was significantly higher than those of the CI strategy group, $F(1,57.18)=18.49$, $p<0.05$. This finding suggested that the GC strategy group had performed better on the conceptual knowledge performance than the CI strategy group.

The total score for procedural knowledge performance was 26. The mean procedural knowledge performance of the GC strategy group was 8.18 (SD=5.58) while that of the CI strategy group was 8.16 (SD=4.59). An independent t-test showed that the difference in means was not significant, $t(63)=0.02$, $p>0.05$. The results showed that there was no significant difference in the mean procedural knowledge performance during the test phase in the learning of the Straight Lines topic between the GC strategy group and the CI strategy group. The effect size was 6×10^{-6} using eta squared value which was considered very small based on [2]. Further, planned comparison test showed that the mean performance on procedural knowledge of the GC strategy group was not significantly higher than those of CI strategy group, $F(1,63)=.04$, $p>0.05$. This finding suggested that the GC strategy group performed as well as the CI strategy group on the procedural knowledge performance.

The means and standard deviations of the instructional condition efficiency index for both the GC and the CI strategy groups, the results of the independent samples t-test and planned comparison test are shown in Table 3. The mean instructional condition efficiency index of GC strategy group was 0.70 (SD=1.31) while mean instructional condition efficiency index of the CI strategy group was −0.73 (SD=1.28). Further, the analysis of an independent t-test showed that the difference in mean was significant, $t(63)=4.46$, $p<0.05$. Therefore, H_o16 was rejected. The results showed that there was a significant difference in the mean instructional condition efficiency index in learning of the Straight Lines topic between the GC strategy group and the CI strategy group. The effect size was 0.34 using eta squared value which was large based on [21]. Planned comparison test showed that the mean 3-D instructional condition efficiency index for the GC strategy group was significantly higher than those of the CI strategy group, $F(1,63)=19.89$, $p<0.05$. The finding indicated that learning by integrating the use of graphic calculator was more efficient than learning using CI strategy.

Table 3. Means, standard deviations, independent sample t-test and planned comparison for instructional efficiency index in Phase II

	Group	n	M	SD	SEM	t	df	p
3-D instructional efficiency	GC strategy	33	0.70	1.31	0.23	4.46	63	0.000
	CI strategy	32	−0.73	1.28	0.23			

7. Discussions

The results for Phase I showed that the GC strategy performed much better on several important performance variables than the CI strategy group. The GC strategy group had performance compared to the CI strategy group. For all these variables, the effect sizes using eta squared indices ranged from .10 to .20 which indicated a moderate to large effects based on [21], implying that the GC strategy was effective in improving students' performance in Straight Lines topic. In addition, the results of experiment in Phase II supported the findings from experiment in Phase I. Overall, the results of this phase provided further evidence that students from the experimental group which undergo teaching and learning using graphic calculators for Straight Lines topic performed better than students from the CI strategy. Specifically, the results showed that the GC strategy group outperformed the CI strategy group such that they had had better scores on overall test performance as well as on conceptual knowledge performance. For all these variables, the eta squared indices were ranged from 0.09 to 0.27 which according to [21] indicated moderate to large effects. These results implied that the GC strategy was effective in improving students' performance in Straight Lines topic. For other performance variable namely the procedural knowledge performance, even though statistically it was not significant, the GC strategy group had higher mean as compared to that of the CI strategy group.

This study confirms earlier studies reviewed by [22] and [23]. Dunham [22] noted that the consensus of her review was that students who use graphic calculators displays better understanding of function and graph concepts, improved problem solving, and higher scores on achievement tests for algebra and calculus. In addition, [23] found that students who use handheld graphing technology have better understanding of functions, of variables, of solving algebra in applied context, and of interpreting graphs than those who do not use the technology. Specifically, a study done by [24] which investigated whether there is a difference in the overall performance on a comprehensive final exam between the graphic calculator instruction and the traditional instruction indicated that the treatment group obtained better performance in the examination. It was also noted that the students' in the graphic calculator instruction perceived that they did more exploration and the tool helped them to understand mathematical concepts better. A study conducted by [25] also indicated that the experimental group using graphing technology performed better in overall understanding of functions without diminishing performance on computation performed without the graphic calculator. Recently, a study done by [26] also indicated a positive effect on the use of graphing technology in learning calculus. The results indicated that the TI-89 hand-held CAS experimental group attained a higher means score than the control group on thirteen out of twenty items. Further, it was found that the most significant differences occurred in items classified as application in which five out of six items significantly favoured the experimental group. Two of the six procedural items showed significant differences favouring the experimental group, while one of eight conceptual items significantly favoured the experimental group.

However, for Phase II, it was found that there were no significant differences in procedural knowledge performance between the GC and CI instruction groups. This finding might indicate that the group had not acquired effective schemas that enabled transfer to be enhanced due to the short duration of intervention (about two weeks) whereby the learning of using the graphic calculator may have interfered with learning of the mathematical content.

Another reason could be that any advantage of using graphic calculator was negated by the split attention effect. In this phase, the split attention effects may result from multiple activities. For example, the GC strategy involves the working on the worksheet (for graphic calculator instructions) as well as the graphic calculator screen. The student is required to refer to both the contents on the graphic calculator screen and the worksheet. These activities provide split attention because students need to attend to more than one sources of information, or more than one activity {[27], [28]}. Hence, transfer performance was hindered during learning.

The results of this phase also showed that the higher performance level of the GC strategy was achieved with a lower mean mental effort during the test phase meaning that the higher performance was achieved with a reduction in cognitive load. This contention was supported by the significantly higher level of 3-D instructional condition efficiency index reported by the GC strategy as opposed to the CI strategy. The findings of this study hence generate an instructional strategy that can be used as alternative to the conventional one namely, the graphic calculator strategy.

8. Conclusion

In this study, integrating the use of graphic calculator in teaching and learning of the topic, Straight Lines, shows promising implications for the potential of the tool in teaching mathematics at the Malaysian secondary school level. The findings from this study have provided valid evidence that to a certain extent, the graphic calculator strategy is superior to conventional instruction strategy. Integrating the use of graphic calculator can be beneficial for students as this instructional strategy has proven to improve students' performance while solving problems. Therefore, the findings from this study imply that graphic calculator strategy is an effective and efficient instructional strategy in facilitating the mathematics learning.

Using graphic calculators in learning mathematics make less cognitive demand (reduction of cognitive load) because a larger part of the cognitive process is taken over by the graphic calculator. This allows students to focus attention on the problem to be solved rather than the routine computations, algebraic manipulations or graphing tedious graphs which require the switching of attention from the problem to the computation, etc and then back to the problem. According to [29], the act of switching attention may blur perception and cause confusion in one's judgment of its temporal properties. This means that reduction of cognitive load and distribution of cognition in graphic calculator medium requires students to focus only on one aspect and enhance the understanding of mathematical tasks. Therefore, more individual will be able to perform mathematical tasks and allow them to work on application problems, thus stimulate students' interest and facilitate the teaching and learning of mathematics.

In this study, the "balance approach" which means "appropriate use of paper-and-pencil and calculator techniques on regular basis" as suggested by [30] with teacher guidance was used for the graphic calculator strategy group. The results of this study showed that the graphic calculator strategy group had better conceptual knowledge performance as compared to conventional instruction strategy group and most important they did not lose procedural knowledge performance. These results reflect the NCTM insistence that "Calculator don't think, students do" [31]. Students will not lose their ability to think if they were to use the graphic calculator. Instead, they need to understand the problem more than what keys to push and in what order. Furthermore, they also need to decide what information to enter, what operation to use and finally they need to interpret the results. Thus, this study also implies that the balanced approach that make the best use of graphing technology in teaching and learning Straight Lines topic enables the development of students' understanding of mathematical concepts without loosing the procedural knowledge.

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