Journal of the Korea Society of Mathematical Education Series D:
Research in Mathematical Education
Vol. 4, No. 1, May 2000, 1-22.

韓國數學教育學會誌 시리즈 D:
<數學教育研究>
제 4 권 제 1 호 2000. 5., 1-22

The Effect of Using Graphing Calculators on Students' Understanding Functions and Attitudes Towards Mathematics and Graphing Calculators[1]

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(Received March 12, 2000)

The purpose of this study was to investigate the effects of using graphing calculators on students' understanding of the linear and quadratic function concepts. The populations of this study are tenth graders at high school in Seoul, one class for the treatment group and another class for the comparison group, and experiment period is 14 weeks including two weeks for school regular exams. Function tests used in the study was proposed which described a conceptual knowledge of functions in terms of the following components:

a) Conceptual understanding,
b) Interpreting a function in terms of a verbal expression,
c) Translating between different representations of functions, and
d) Mathematical modeling a real-world situation using functions.

Even though the group test means of the individual components of conceptual understanding, interpreting, translating, mathematical modeling did not differ significantly, there is evidence that the two groups differed in their performance on conceptual understanding. It was shown that students learned algebra using graphing calculators view graphs more globally. The attitude survey assessed students' attitudes and perceptions about the value of mathematics, the usefulness of graphs in mathematics, mathematical confidence, mathematics anxiety, and their feelings about calculators. The overall t-test was not statistically significant, but the students in the treatment group showed significantly different levels of anxiety toward mathematics.

[1] This work was supported by 1998 Ewha Womans University Research Fund and Texas Instruments Research Grant.

INTRODUCTION

The reform movement initiated by the NCTM Standards gives rise to the need to consider uses and integration of educational technologies, especially graphing calculators in mathematics education. Graphing calculators can be used by students to facilitate use of promoting construction of learning by asking appropriate questions to monitor their own thinking. Furthermore, the National Council of Teachers of Mathematics (1998) pointed out that students should be able to access to graphing calculators to solve various and complex problems. When they use graphing calculators, the results of the development of their problem solving strategies and achievements show positive effects on their uses in the United States. However, little research exists about the evidence of the appropriate and realistic use and integration of graphing calculators in Korea.

This study examined whether high school students' achievement and attitudes toward mathematics and graphing calculator in regular advanced algebra classes under Korean educational circumstance could be developed through the use and integration of graphing calculator on problem solving related to functions.

THE USE AND INTEGRATION OF COMPUTER TECHNOLOGIES IN MATHEMATICS EDUCATION

Mathematics teachers are required to be more proficient in using and helping students use instructional technologies to develop, enhance, and expand students understanding of mathematics by encouraging mathematical investigations at all levels (NCTM, 1991). These technologies include computers, appropriate calculators, multimedia devices, Internet, and other emerging educational technologies.

The uses and integration of instructional technologies in mathematics education are well documented (e.g. Clements & Gullo, 1984; Dreyfus & Halevi, 1990; Dugdale, 1982; Goldman & Barron, 1990; Magidson, 1992; Miller, Kelly & Kelly, 1988; Schoaff, 1993). A study on the effectiveness of Logo programming on problem solving and spatial relation ability (Miller et al., 1988) was conducted with two fifth-grade and two sixth-grade classes that were assigned to either a Logo group or a control group. In the Logo treatment, the students were encouraged to plan and produce their own drawings in pairs. The control group did not receive any Logo instruction, instead attended regular mathematics class. As results, the Logo group showed significantly higher scores than the control group on the measures of Logo-related and problem solving skills, and on mental rotations on geometric tests.

To provide entailments of student-centered instruction in a technology-rich classroom, Magidson (1992) designed and taught a computer software, GRAPHER, to a Foundations of Algebra class with 22 junior high school students about to enter eighth and ninth grade in the summer of 1991. Magidson (1992) elaborated on the capability of computers to dynamically display simultaneous changes in graphical, algebraic, and tabular representations with rich environment for stimulating learning.

Dreyfus & Halevi (1990) conducted a case study of tenth-grade student computer interaction using a program of Quadfun, a computer-based open-learning mathematical environment. According to Dreyfus & Halevi (1990), a learning environment dealing with families of quadratic functions provides a framework for exploring questions, such as how many and which givens determine a unique parabola as well as how a parabola changes if the parameters in its algebraic representation are changed.

RESEARCH ON GRAPHING CALCULATORS

Research on the effects of graphing calculator has already made rapid progress as well as its development. The use of graphing calculator in class is avoided on account of the concern that students tend to achieve lower in basic operations and problem solving. However, the other way, students can do better in problem solving by using computer or calculator because they can compute using several methods, select proper process, find a solution and decide whether the solution is correct or not (NCTM, 1989). By using graphing calculator, they can solve the problem that had not been solved before. They can understand the mathematical concepts widely by experiencing in realistically situated problems. It must be a great help for student in basic computation and problem solving.

In addition, the graphing calculator is available for all grades, from kindergarten to university, in using properly. NCTM (1989) suggests that graphing calculators would be available to all students at all times. Actually, according to the results of meta-analysis of Hembree & Dessart (1986), students over Grade 5 who used graphing calculators with traditional instruction could maintain their paper-and-pencil skills without apparent harm except Grade 4 and the use of graphing calculator made them do better in basic operations and problem solving.

Moreover, there are many results that it affects in achievement positively as well as in problem solving. In the study of Hembree & Dessart (1986), their use of graphing calculators brought much higher achievement scores both in basic operations and in problem solving at all grades and all level. Especially, Chandler (1992) pointed out that students who use the graphing calculator on the transformation of functions at a high school in Huston to explore, propose, and build connections among the numeric, graphic, and algebraic representations of functions have a better understanding of the relationship between a function and its graphical representation.

The research on the effects of using graphing calculator is also processing in the face of meta-analysis. Hylton-Lindsay (1997) found that graphing calculator enhanced the metacognitive aspect of students' performance, particularly their thinking processes and their ability to self-regulate. Hollar's study (1996) supported current mathematics theory that technology has the potential to help facilitate the development of structural conceptions of function (Hollar, 1996).

In addition, graphing calculator brings the positive effect on student's emotion. The graphing calculators benefit student achievement greatly in problem solving, especially for both low- and high-ability students and positive attitudes related to its use can help relieve students' traditional dislike of word problems (Hembree & Dessart, 1986). Students with calculators have better attitudes toward mathematics and better self-concepts in mathematics than students without calculators at all grades and all levels. Students possess more positive attitude and response by changing the atmospheres of class as they use graphing calculators. Therefore, the use and integration of the graphing calculator in algebra will improve students' achievement and their attitudes for nontraditional students for other students who depend on the teacher (Austin, 1996).

The graphing calculators have a positive influence on students' interest in mathematics (Hylton-Lindsay, 1997) and as receiving the feedback, uncertainty of the results reduces and an anxiety about mathematics disappears (Ruthven, 1990). Farrell (1990) mentioned that students are absorbed harder in a class when they use graphing calculators and do more group activities, investigation and exploration, and problem solving. As a result, students using graphing calculators in a class have more positive attitudes and more confident than non-calculator students at all grades and ability levels (NCTM, 1983).

Particularly, when male and female students equally use graphing calculators in a class, female students consistently show greater gains over male students according to Nimmons (1997), Bosche (1997), Ruthven (1990) and Dunham (1990, 1992).

Several positive effects obtained by using graphing calculators as described above will bring to change forward in mathematics education. First of all, it will produce the changes in mathematics teaching and learning methods. The graphing calculators allow students to visualize the problem, to find their own mathematical theorem, to confirm appropriateness of their solution, to test their own hypothesis, and to explore various methods to solve problems (Pomerantz, 1997). The teachers facilitate students' experiments and they make students arrange their ideas and have a chance to relate what they learned as teacher and students developed their thoughts and dynamical instruction to work out mathematical matters (NCTM, 1989).

While some mathematics becomes less important due to being replaced by technologies, some mathematics becomes more important due to the need for technologies (Murdock, Kamischke & Kamischke, 1998). Thus, what is important in mathematics and what is to be taught are being changed. Therefore, we can give a new significance to things that have been dealt less important until now in mathematics education. The chance to reconsider our educational system can be provided.

Even graphing calculators' application plans are provided with centering around the teacher's research groups and graphing calculators are already used and developed in school in many other countries such as the United States and Canada, there exists few study of the effects of graphing calculators in Korea. There is few model about how to use graphing calculators. However, the results of other countries should be understood with reconsideration because the situation in Korea is very different from others. Obviously, it is not believed that research about graphing calculator don't exist in Korea. For instance, since graphing calculators are introduced to Korean schools, there are several studies (e.g., Whang, 1997; Kim, 1997; Kwok, 1996; Kwon, Kim & Park, 1998; Kwon, Kwon & Choi, 1998; Kwon & Park, 1997; Kwon et al., 1997; Kwon, Park & Jeong, 1998). However, these researches are only descriptive studies on how to utilize graphing calculators in mathematics education.

As a theoretical model for function, in the 6th curriculum of Korea, the purpose of mathematics lies in developing mathematical abilities and attitudes, in which students tend to observe mathematics in real world situations, to reason, and then to solve the problems (MOE, 1994). Kaput (1989) describes the problem solving process as a cyclical one where one reads a description of a situation, builds a cognitive representation of the situation describing certain features of the quantitative relationships involved, and then projects this representation onto external representation. Function plays a central role in this process. Therefore, theoretical models for function were divided into mathematical modeling, interpretation, translation, and additionally conceptual understanding.

First, mathematical modeling is a problem solving, which translates real problem situation into mathematical problem situation or representation (see Figure 1).

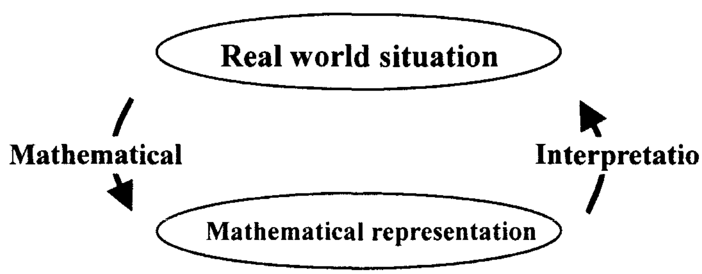

Figure 1. Relation between mathematical modeling and interpretation.
(Source: O'Callaghan, 1994)

The term 'mathematical model' means a mathematical representation of relationships within a complex phenomenon. Mathematical models can be used to clarify understandings of the phenomenon and to solve problems.

In this sense modeling includes not only representation but also acting upon representation and interpreting the meanings of one's actions within the mathematical model and with respect to the phenomenon being modeled (NCTM, 1998). The NCTM (1989) recognizes the incidence of functions in all mathematical topics and their uses for modeling real world situations. In addition, it involves ability selecting appropriate representations corresponding to the problem situation.

Second, interpretation is a process that expresses in terms of verbal form by reading information from mathematical representations. Briefly, it is described as the reverse procedure of the mathematical modeling process (see Figure 2). Interpretation can also be divided into sub-components. At the high school level, there is a greater number and type of mathematical objects and relationships that students should be expected to represent and interpret.

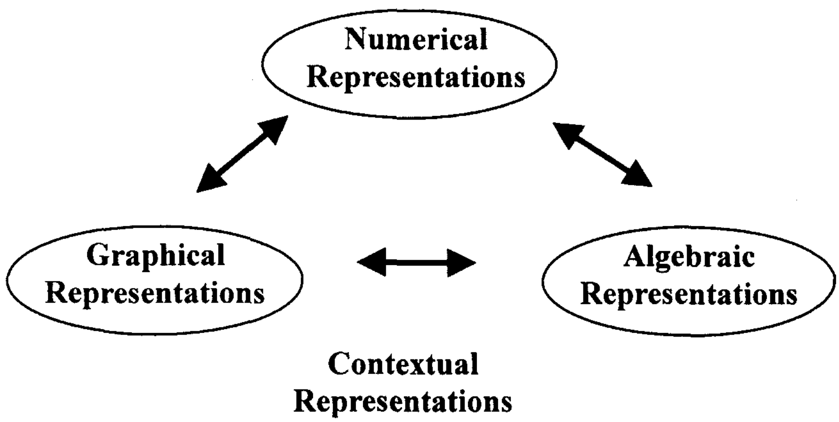

Figure 2. Translations between mathematical representations (Source: Heid, 1995).

Third, a translation is the ability to move from one representation of a function to another (O'Callaghan, 1994). Flexibility in translating among representations of functions is important because students have different goals at different times, and the goal or context should determine which representation is most appropriate (Schoenfeld, 1992). A different problem dealing with the same phenomenon might be more profitably approached with a different representation. Also students can more easily understand functional relationships in more than one representation and, based on this understanding, select representations that most effectively communicate desired information (Hector, 1992). As mentioned previously, the advantages of technology are particularly evident for this translating ability.

Last factor of theoretical model for function is a conceptual understanding. It is also involved in other abilities. But it is limitedly defined as pure concepts in this study. That is, it involves concepts of domain, range, scale of graph, properties of function families and so on. Students can draw many graphs and analyze using calculator's capabilities such as zooming and tracing. It increases their understanding of fundamental and important concepts.

METHOD

Subjects

Differently from works above, this study focused on the effects on students in an academic high school using graphing calculators consistently on learning functions for one semester. This research was conducted to investigate the students' understanding of the function concepts and attitude toward functions in the treatment group could be improved when graphing calculator was used in learning function. This study emphasized on the concrete effects of graphing calculators and students' reactions, particularly visual effects, dynamics, translation of the different representations of functions by using graphing calculators. The tenth graders at middle-sized high schools were the population of this study: one class for treatment group and another class for comparison group (see Table 1). In this study, all of students in the treatment group could access TI-83's individually at school as well as at home. It deals with the range of complex numbers and allows students to trace a graph and scroll table values simultaneously.

Table 1.
Number of subjects

Group / Student Number	Comparison Group	Treatment Group
Boys	22	23
Girls	23	26
Total Number (N)	45	49

Procedures

Both treatment and comparison groups were taught functions by one teacher. The experiment period was 14 weeks including 2 weeks for school regular exams such as mid-term and final exams. The treatment group was emphasized on the concept of function using graphing calculators. The teacher used a view screen and overhead projector for showing calculator's operation. Based on textbook, worksheets were provided to students in order to teach how to learn functions using graphing calculators. The comparison group learned functions with only textbook by traditional paper-and-pencil method.

Test Instruments

Instruments used in the study included function tests, achievement tests, and attitude survey for mathematics and graphing calculator.

Table 2.
Instruments of this study

Test	Treatment Group	Comparison Group
Function	pre-test, post-test 1, post-test 2,	pre-test, post-test 1, post-test 2,
Achievement	Midterm & final examination	midterm & final examination
Attitude toward mathematics	pre- & post- survey	pre- & post- survey
Attitude toward graphing calculator	pre- & post- survey	not administered

Function tests. Function tests were developed in order to measure four components of theoretical model for function, namely mathematical modeling, interpretation, translation, and conceptual understanding, three times (pre-test, post-test 1, and post-test 2). As mentioned previously, tests were consisted of 4-criterion. The validates of this tests (Cronbach α) were evident through pilot test and questions were based on instruments of Rich (1990), Ottinger (1993) and O'Callaghan (1994). The pre-test and the post-test are consisted similar type of questions with different content. The pre-test was performed in order to measure the knowledge of function concept, linear and quadratic functions before experiment. Post-test 1, developed parallel with pre-tests, was tested in the middle of the experiment (after midterm exam). When experiment was over (after final term exam), post-test 2 parallel with pre-test which has same assessment criterion and involved all content of functions was performed (see Appendix).

Achievement tests. Achievement tests come from school regular examination data of mid-term and final exams. The mid-term and the final exams were conducted at 9th, Oct. 1998 and at 8th, Dec. 1998, respectively. Overall, questions were used to test the abilities of symbolic manipulations and transformations on algebraic representations of function (see Table 3).

Attitude surveys. Two instruments were used to evaluate students' attitudes toward mathematics and graphing calculator with Likert scales. They were administered at the beginning and the end of the semester.

Table 3.
Question criterion and assessment content of function tests

Question Number	Assessment Criterion*				Assessment Content
	A	B	C	D	
1		B3			Students can read a necessary information from graph.
2 (1)	A		C2		Students can translate between graph and equation.
(2), (3)					Students know the properties of function families.
3 (1),(2)		B1	C1		Students can read a necessary information from table.
(3)					Students can translate numeric representations into Graphical representation.
4		B2			Students can interpret the meaning of equations.
5	A				Students understand the concept of independent and dependent variables.
6	A				Students can know that the shape of a function is decided According to the scales of x- and y-axes.
7 (1), (2)					Students can translate between graph and equation.
(3)	A		C2		Students can know that given functions are the relations of translation.
8				D1	Students can represent given verbal situation as equation.
9				D2	Students can represent given situation by graph and attend to x-intercept and slope of graphs.
10	A				Students know the number of function, which pass given three fixed points in coordinate plane, i.e. they understand the definition of function.

*Assessment Criterion
A: Conceptual Understanding
B: Interpretation
- B1: Interpretation from table
- B2: Interpretation from formula
- B3: Interpretation from graph

C: Translation
- C1: Graph from table
- C2: formula from graph

D: Modeling
- D1: Modeling to formula
- D2: Modeling to graph

They are measured not only to provide an initial comparison between the treatment and comparison groups but also to determine the effects of graphing calculator on students' affective domain. Pilot studies were conducted on these tests at a high school in Seoul. Mathematics attitude survey with 19 questions modified from Aiken (1972) was implemented two times before and after experiment to both of two groups. The questions that were not related with this study or overlapped were deleted and some questions about graphs of function were added. The graphing calculator attitude survey was implemented after using graphing calculator in the treatment group in order to observe and verify how students change their attitude toward graphing calculator.

Two tests (pre- and post-tests) with 19 questions were conducted only to the student in the treatment group. This questionnaire was based on Rich (1990) and developed in terms of mathematics and graphing calculator.

DATA ANALYSIS AND RESULTS

Function Tests

The function tests were administered to the student in each class at three times. One is pre-test and the others were two post-tests (post-test 1 & 2). Both of the treatment and comparison groups took the test on the same day. In both groups, students couldn't use calculators on the function tests (see Table 4).

Table 4.

Mean, standard derivation and t-value on the Function Tests (pre-, post-1, post-2)

	Treatment (N=42)		Comparison (N=38)		Difference	
	M	SD	M	SD	*t*	*p*
Pre-test	29.51	9.91	30.84	9.86	-.597	.552
Post-test 1	24.61	10.42	26.53	10.86	-.799	.427
Post-test 2	30.20	11.23	28.45	9.90	.735	.465

The mean of the treatment group was lower than the comparison groups mean on the pre-test but was not on the post-test 2. Although the data show a higher mean in the treatment group, the difference was not great enough to reject the null hypothesis on the post-function test 2. On two post-tests, there was no significant difference between the treatment and comparison groups either. On the other hand, the ANCOVA was tested to determine whether students score in the treatment group using graphing calculator integrated with designed-material would be significantly higher than students some in the comparison group. This analysis was used to determine if there was any significant difference between the mean score of those using calculator and not using them. It was implemented for the function post-test 2 with the scores from the corresponding pre-function test used as a covariate (see Table 5). It shows that there was no significant difference not only in total score but also in four components of theoretical model. All of the four components were corresponding with them of pre-function test.

Using analysis of covariance, the data supports the null hypothesis of no significant difference between mean scores of the two groups of the post-test 2 ($F(1,76)= .176$). Although the treatment group had a higher adjusted mean (Treatment group: 30.61; Comparison group: 28.00), the difference was not great enough to reject the null hypothesis. There was no significant difference in the function achievement between two groups.

Table 5.

Result of ANCOVA comparison on Function post-test 2

	Source	SS	Df	MS	F
Total score	Pre-test	3152.38	1	3152.38	44.110
	Class	133.57	1	133.57	1.869
	Error	5431.45	76	71.47	
	Total	76717.00	79		
Understanding of the function concept	Pre-test	851.93	1	851.93	42.332
	Class	17.16	1	17.16	.853
	Error	1529.48	76	20.13	
	Total	6983.00			
Translation	Pre-test	38.93	1	38.93	7.288
	Class	.70	1	.70	.132
	Error	406.01	76	5.34	
	Total	3686.00	79		
Interpretation	Pre-test	105.06	1	105.06	5.659
	Class	4.60	1	4.60	.248
	Error	1411.10	76	18.57	
	Total	15632.00	79		
Modeling	Pre-test	19.81	1	19.81	8.380
	Class	3.17	1	3.17	1.341
	Error	179.63	76	2.36	
	Total	510.00	79		

Achievement Tests

Mid-term and final exams were used to assess the achievement of both of the treatment and comparison groups. Overall, the questions were used to evaluate the computation and comprehension abilities of the function in the algebraic/symbolic representations. Only questions connected with the contents of function were analyzed for this study because mid-term test had questions separated from the function unit. Total score of the questions of the mid-term test is 25 points. In addition, 90 points were considered as the total score of the final test regarding this research since 10 points of 100 points was the student's performance score. The difference of two groups was analyzed by *t*-test in the following table.

Table 6.
Result of t-test between two groups on the mid and final tests

	Total score	Treatment (N=42)		Comparison (N=38)		Difference	
		M	SD	M	SD	*t*	*p*
Mid test score	25	11.71	7.04	9.47	5.90	1.522	.132
Final test score	90	33.37	21.20	28.16	17.91	1.175	.244
Mid + Final	115	45.07	24.69	37.63	21.78	1.416	.161

Attitude surveys

The attitude survey was conducted to assess the students' attitude and perceptions about the usefulness of mathematics and their feeling about mathematics and graphic calculator. To compare the mean attitude of the treatment and comparison groups, as measured by this Likert-scale survey, a t-test was performed on the weighted responses. For the positively stated statements, a value of five was assigned to strongly agree, four to agree, three to undecided and so on. The assignment of values was reversed for the negatively stated statements. A total of 95 were possible for 19-item questionnaire.

Attitude toward mathematics. Table 7 shows the results that which favor the treatment group on four components of mathematics attitude: value of mathematics, value of graph in mathematics, self-confidence about mathematics and sense of easiness about mathematics. There was no significant difference on the pre- and post- attitude to mathematics between treatment and comparison groups except on sense of easiness about mathematics of the pre- attitude survey. Treatment group scored far better than the comparison group on this sense. That is to say, this shows that the students in the treatment group recognized mathematics easier ($t = 2.160$, $p = .034$).

Table 7.

Result of t-test on the pre- and post- attitude survey toward mathematics

		Treatment (N=42)		Comparison (N=38)		Difference	
		M	SD	M	SD	T	P
Pre-test	Score	2.98	.77	2.76	.65	1.423	1.690
	Value of mathematics	3.14	.92	2.87	.86	1.340	1.177
	Value of graph in mathematics	3.05	.78	3.09	.63	-.191	-.032
	Self-confidence	2.74	.99	2.49	.83	1.181	.092
	Sense of easy	2.97	.97	2.61	.86	1.653	2.160
Post-test 2	Score	3.09	.46	2.91	.49	.159	.095
	Value of mathematics	3.19	.73	2.99	.75	.184	.243
	Value of graph in mathematics	3.30	.63	3.31	.57	.849	.975
	Self-confidence	3.01	.59	2.99	.64	.241	.927
	Sense of easy	2.92	.75	2.52	.92	.102	.034*

* significant difference at $\alpha = .05$

Attitude toward graphing calculator. Data from thirty-seven students were collected and analyzed. The questions on attitude toward graphing calculator were composed of 19 items questionnaire with three components: value of graphic calculator, necessity of graphic calculator and self-confidence about the graphing calculator use. There was no significant difference between pre-test and post-test when a *t*-test was used to observe the change of their attitude to graphing calculator (see Table 8).

Table 8.

Result of t-test on the pre- and post- attitude survey toward graphing calculator

Test	Total mean score (N=37)		Value of graphic calculator		Necessary of graphic calculator		Self-confidence about graphic calculator use	
	M	SD	M	SD	M	SD	M	SD
Pre-	3.55	.62	3.58	.64	3.95	.61	3.11	.94
Post-	3.53	.40	3.39	.44	3.77	.41	3.37	.65
t	.777		1.519		1.542		-1.404	
p	.440		.134		.128		.165	

But the other scores except self-confidence about graphing calculator use were lower than pre-test score. It suggests that there is a possibility that the students in the treatment group very widely responded to pre-questions before the experiment.

CONCLUSION

The purpose of this study was to investigate the effects of using graphing calculators on students` understanding of the function concepts. It has a meaning in the sense of being the first experimental research using graphing calculators conducted in Korea. The followings were drawn from the study and addressed the research questions explored in the study. This study does not provide strong evidence of an overall achievement effect of using graphing calculators in algebra class. Since the achievements tests used in this research were mainly at computational or comprehension levels, this results would be understood as that the use of graphing calculators has neither damaged nor improved the students' computational skills.

Function tests used in the study was proposed which described a conceptual knowledge of functions in terms of the following components:

a) Conceptual understanding,
b) Interpreting of a function in terms of a verbal expression,
c) Translating among different representations of functions, and
d) Mathematical modeling of a real-world situation using functions.

The group test means of the individual components of conceptual understanding, interpreting, translating, and mathematical modeling did not differ significantly.

The attitude survey assessed students' attitudes and perceptions about the value of mathematics, the usefulness of graphs in mathematics, mathematical confidence, mathematics anxiety, and their feelings about calculators. Even though overall t-test was not statistically significant, students in the treatment group showed significantly differ levels of anxiety toward mathematics. It means that graphing calculators can be used as a tool reducing mathematics anxiety in learning mathematics.

The research focuses on students' achievement and attitude as well as the dynamics of the classroom. Students in both of treatment and comparison groups of this study that focuses on different classroom and student behaviors would provide more data on how the graphing calculators affect the teaching and learning of mathematics. More studies are needed that focus on the way in which the use of technology in mathematics classes changes what and how teachers test. If students are allowed to use graphing calculators in assessment, then new tests are needed to be devised and validated. Teachers need to be aware that their tests are measuring what they are supposed to measure. More studies are needed to help mathematics educators fully understand the impact and appropriate uses of graphing calculators in the mathematics classroom. Professional development of the use of the graphing calculators and integration of graphing calculators in active mathematics classes is a research area that deserves continued attention.

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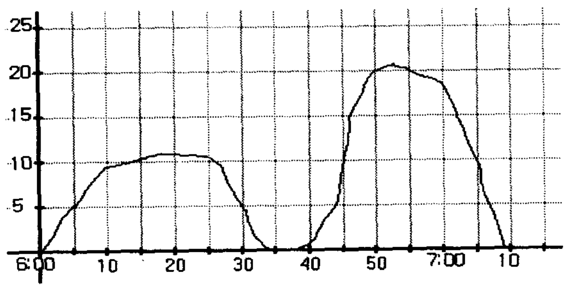
APPENDIX: FUNCTION TEST

1. The graph below gives the speed of cyclist on his daily training ride. During his ride, he must climb a hill where he pauses for a drink of water before descending. Use this graph to answer the following questions as accurately as possible.



① Find the speed when time equals 25minutes.

____

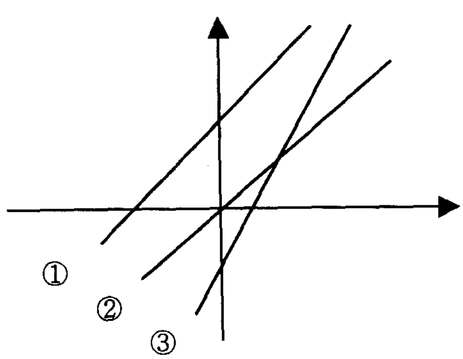
② During which 10-minute intervals was the speed increasing?

____

③ When was the cyclist at the top of the hill?

____

2. The following graphs represent functions $y=2x+3$, $y=3x-1$, $y=2x$ respectively.
  1) Find the appropriate equation of ①, ②, ③, respectively.
  2) Using given graphs, draw the graph of $y=3x+3$ on the coordinate plain below.



① ______________________

② ______________________

③ ______________________

3) Explain how to use given graphs in order to draw the graph of .

____

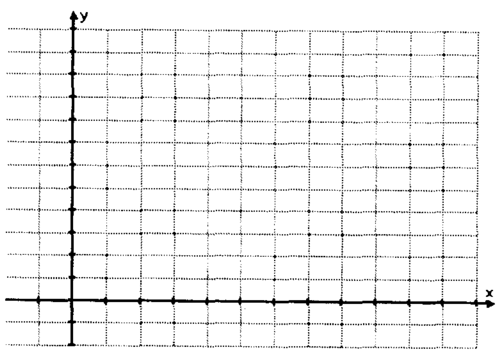
3. A roast is taken from the refrigerator and put into an oven. Below is a part table of its temperature, in degree (D), recorded during the first 120 minutes (M).

M	0	10	20	30	60	120
D	10	38	60	77	93	104

① Find the domain of this situation ______________________

② Find the range of this situation ______________________

③ Draw a graph of this situation ______________________



4. Suppose that you sales the ticket of school broadcasting festival. Your profit (P) is determined by the number (n) of tickets sold according to the following formula (P : ₩1000)

$$P(n) = -0.1n^2 + 16n - 150$$

Describe briefly in words the information that is expressed by the following equations.

① $P(100) = 450$

____

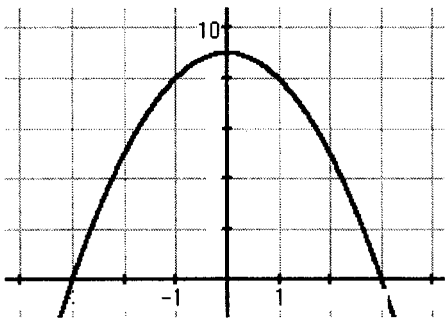
② If, $n \langle 10$, then $P(n) \langle 0$

____

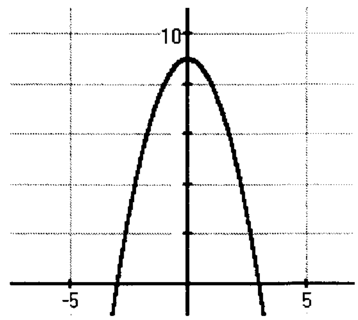
5. If y is a function of x, what happens to y when gets larger?
① y gets larger.
② y gets smaller.
③ y doesn't change.
④ y changes.
⑤ Not enough information to tell.

6. Which are graphs of the same function?

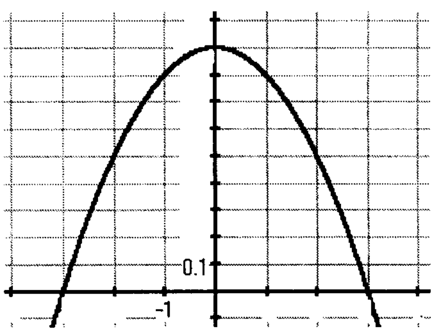
a)



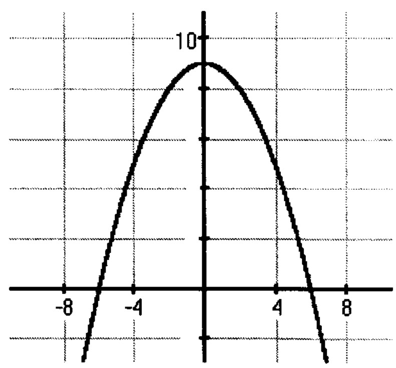
b)



c)

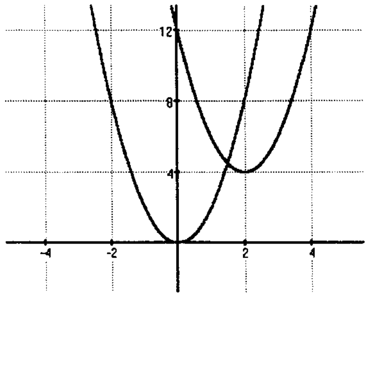


d)



① a, b ② a, c ③ c, d ④ a, d ⑤ b, d

7. The following graphs represent. Find and describe relation of two given functions.



① b =
② c =
Relation of two given functions

____

____

8. Hosun should go quickly from her house to Ewha woman's university by taxi. The fare is ₩1300 fundamentally and ₩100 is added per 0.2km. (The fare isn't increased for first 2km.)

Find the cost from her house to Ewha woman's university.

____

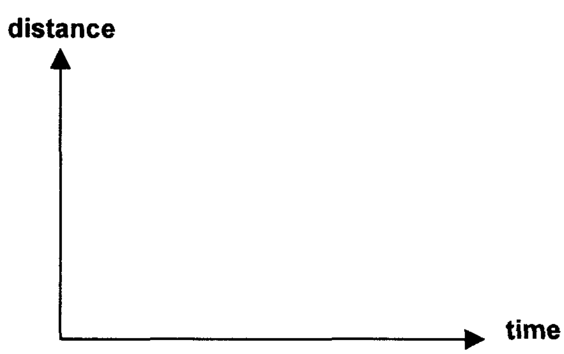
How far is the distance of two places if the cost is 5800 won?

____

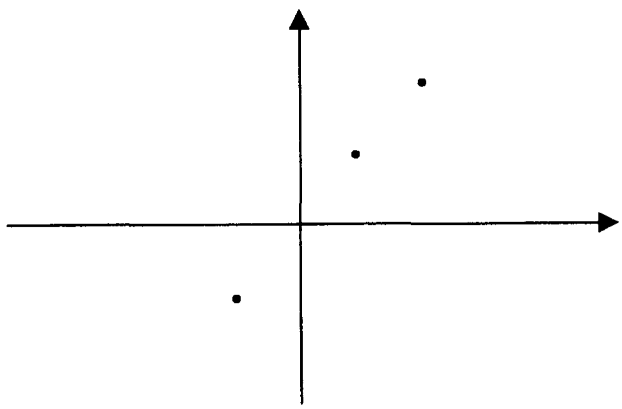
Find the equation of this situation.

____

9. Leonardo Dicaprio don't get a ship, which is Titanic. Because motorboat's velocity is faster than Titanic, he runs after the ship by motorboat and got it. (Titanic and motorboat move by constant velocities. Distinguish and mark the name of graphs.)



10. In the given coordinate system, draw possible graphs of a function that pass through three given coordinates.



What's the number of function passing through these coordinates?