# Implementation of Graphing Calculator in Intermediate Algebra with Function Approach in Community College

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Abstract

A major goal of this paper is to document changes that occurred in developmental mathematics classrooms in the community college setting when the graphing calculator (GC) Texas Instruments (TI)-83 was introduced to students. The six-week intervention was conducted during the section of Intermediate Algebra in the Community College Baltimore County (CCBC)-Essex. To measure the effect of GC on student achievement in Intermediate Algebra class, a pretest/post-test and statistical paired t-test (one-tailed) were conducted.

To measure student attitudes regarding the use of GC throughout the intervention, pre/post-surveys and statistical paired t-tests (one-tailed) were conducted.

The results of the intervention show that there is a significant gain in student achievement and a gain in student attitude toward GC in Intermediate Algebra class with the use of GC.

# Introduction

## *Focus of the Intervention and its Purpose*

An educator's most important goal is students' academic achievement. According to Dixon (2003), academic achievement has three components: (1) conceptual as "the head of learning", (2) affective as "the heart of learning", and (3) "the hand of learning" that corresponds to the level of opportunity of challenging academic tasks (p. 5). Educators can use this structure to identify the goals of any educational intervention. The goals of the interventions can be defined as either conceptual or affective or both. Under conceptual, "the head" and "the hand" of learning are joined. An example of conceptual goals would be the developing of skills, literacy, and test taking proficiency. Affective goals relate to feelings where the issues exist around a desire to learn work ethic and focus. Examples of affective goals would be the developing of confidence, attitude, reality checks, and optimism.

The goals of the intervention are both conceptual and affective. The presented intervention is designed for teaching the concept of functions to Intermediate Algebra students in a community college. It will help them visualize the graphs of the functions using the graphing calculators TI-83.

## *Conceptual Framework*

### *Teaching of the Function Concept*

Functions and their algebraic, tabular, and graphical representations are introduced to students in secondary school. Usually the topics covered are linear, quadratic, cubic, exponential, logarithmic, and trigonometric functions. The importance of understanding the function concept can not be overemphasized. The concept of function underlies all algebraic thinking.

The literature explores several aspects of the structural and procedural interpretations of the functions. According to Kieran (1992), the research shows, that the teaching of functions emphasizes their structural rather than procedural interpretations. Kieran (1992) states that students try to avoid the more formal structural representations and interpret functions as procedures for computing one value by means of another. Students prefer procedural conceptions in understanding of functions with respect to algebraic forms of representation. It was also was found that students are not prepared to interpret graphical representations from a structural view.

It might be concluded from the studies that students need to treat functions as procedures for a significant period of time. The research suggests that instructions should be improved in order to help students fill a gap between procedural and structural conceptions of functions. Kaput (1989) has described in detail how technology can be used to assist students in creating links among the various two-variable notational systems: tables of data, coordinate graphs, and equations. Except for graphs, which permit structural view, most of the cognitive activity involved in working with these notations remains at the procedural level (Kieran, 1992). The transition between the two conceptions still hardly occurs.

*Electronic Technology as a Cognitive Tool for Learning of Mathematics*

With an availability of electronic technology (ET) since the late 1980s, mathematics education has undergone a great change. Technology has been an important part of this change (Heid, 1997). The reason for the major impact of technology on the reform in mathematics education is its effect on the cognitive processes -- nature of mathematical thinking and understanding. From this perspective, a concept of “cognitive technologies” is used to investigate the impact of technology on mathematics education. According to Pea, “cognitive technologies” are defined as media that help “transcend the limitations of the mind…in thinking, learning, and problem-solving activities” (as cited in Heid, p. 36).

In mathematics education, reform occurred in algebra and calculus. In algebra reform, the concept of function was emphasized. The cognitive tools are used to move students from procedural knowledge to conceptual understanding of functions (Heid, 1997). In calculus reform, along with reduction of computations and concentration on the concepts, the emphasis was made on visualizing of the problem. As a result, the reform has produced the shift in pedagogical philosophy from behavioral to constructivist, from introverted learning to cooperative, with emphasis on conceptual understanding (Kulik, 2003). ET is also important from the constructivist view because it provides different models of multiple representations that help students to build conceptual connections. Among the cognitive tools used in mathematics education are graphing calculators (GC). They give students easy access to computational and graphical results.

*Needs Analysis*

Today, technology has taken its place in almost all classrooms in schools and colleges across the country. A position statement of NCTM (1998) on the use of calculators strongly urged that calculator usage be promoted by school districts, teachers at every level, authors, and educators. In view of NCTM’s (2000) position on the use of ET, there is a need to use the graphing calculators for mathematics teaching, particularly, algebra.

To define a need for the proposed intervention, a survey on the need assessment was sent via e-mail to the faculty members teaching Developmental (Elementary/Introductory and Intermediate) Algebra in the Community College of Baltimore County (CCBC)-Essex (Appendix A). Out of 49 surveys sent, 10 were answered. In general, results of the collaborative survey show that the implementing of GC in the teaching of developmental mathematics is necessary. GC enables the students and teachers to spend less time on redundant tasks and allows more time to be spent with exploration of the concepts. It also allows them more freedom to work together. This is especially important when working with adults in developmental mathematics at the community college level.

## Methodology

### *Educational Objectives*

A major goal of this report is to document changes that occurred in developmental mathematics classrooms in the community college setting when GC (namely the Texas Instruments TI-83) was introduced to students with different educational backgrounds.

The intervention focuses on the logical framework and consistency of algebra. The educational objectives are the following: understand relations and functions and selection, convert flexibly among, and use various representations for them which are consistent with the *Principles and Standards for School Mathematics* (NCTM, 2000). The use of the graphing utilities makes the study of function concepts and their applications accessible to all students. Using graphing calculators, students observe the behavior of many types of functions.

### *Description of the Intervention*

The intervention includes a greater emphasis on the variety of the representations of the functions and on conceptual understanding and performing transformations of the commonly used functions. The intervention contains the following: (a) the intervention starts with a pre-test/survey; (b) the students learn the concept of function through the five conventional presentations of the different descriptive ways of the functions; (c) the lessons contain motivational discussion, exploration, practice, final summary, and assessment; (d) the intervention ends with a post-test/survey.

A major goal of this report is to document changes that occurred in developmental mathematics classrooms in the community college setting when GC was introduced to students with different educational backgrounds.

*Intermediate Algebra in a Community College Setting*

Community colleges offer developmental mathematics courses for the students that come from the K-12 setting and are not prepared for university level. Developmental mathematics courses at the college level have been created to serve as remediation. These courses are helping students to prepare for university level mathematics courses that are transferable. Transferable courses count toward a bachelor’s degree requirement. Developmental courses are not transferable, but in some cases count toward an associate’s degree requirement. Intermediate Algebra is one example of a developmental mathematics course taught at the college level. It corresponds to the Algebra II course in a high school setting. The overall content is usually the same. At the college level, the course is taught in one semester while the high school equivalent is taught in one academic year.

The demand for developmental mathematics courses is clear due to the lack of preparation for university level courses. Therefore, it is crucial that new methods emerge to meet the demand for mathematics skills and to help create opportunities for the students. GC helps to build conceptual understanding through procedural problem situations, maintaining the adult learners’ interest. This is important when teaching adults in the community college.

*Setting of the Intervention*

The six-week intervention was conducted during the morning section of Intermediate Algebra (MATH-083) over the course of the fall semester of 2005 in the CCBC-Essex. The sections are completed by the registration office from the following student contingency: former high school graduates who have scored low on the college entrance test; college students who have successfully completed previous developmental courses (Elementary/Introductory MATH 081/082); college students who have before dropped or failed the course. Initially, the class contained 22 students. By the end of the semester, it contained 18 students. The pre-test/survey results of the dropped students were not included in the data.

The physical setting of the intervention appears rather traditional. Much of the intervention content was delivered to students via chalkboard and an overhead projector by using the transparencies with the course content. An overhead projector with screen and GC TI-83 were used to demonstrate work of GC. In each class, emphasis was placed on the use of GC for graphing and solving the problems. During the intervention, the social aspect of learning mathematics was very important. This process was fostered as students worked collaboratively on many problems and exchanged the experiences of GC use.

Intervention topics were presented using a mixture of instructional approaches. The instructor generally used a lecture format with time for practice problems in class. The intervention was based on the textbook *Intermediate Algebra* second edition by Martin-Gay (2003) by adding on the use of GC into an existing developmental mathematics curriculum. The use of GC is not required by the textbook; however, some explorations of GC are present. These explorations were used in the intervention. Before the intervention, it was unclear if a reorganization of certain topics would better facilitate GC usage in developmental mathematics classroom. Insignificant curriculum re-sequencing was employed for this intervention to be completed in six weeks with one intervention class per week.

*Features of the Intervention*

The different aspects of the final characteristics of a GC-enhanced class were compared to the pre-intervention characteristics. The class was examined as it existed prior to the use of GC and after the use of GC. In this case, the features of presented intervention did retain features of a classic pretest/posttest study in mathematics education.

Some limitations of the intervention might be caused by some additional time for students to feel comfortable with GC, particularly for those that had never used GC before. The students were not allowed to use GC on the pretest, and were allowed to use GC on the posttest. GC TI-83 was required for use by all students during the intervention. Students did have accessibility to GC by borrowing it in the college library.

*Data Collection*

The data collection methods included the following: (a) statistical pre/post-test and paired t-test (one-tailed) designed to measure the effect of GC on student achievement in Introductory Algebra class; (b) statistical pre/post-surveys and paired t-test (one-tailed) designed to measure student attitudes regarding the use of GC in Introductory Algebra class throughout the intervention. Data collection instruments are described below.

*Measurement of Students' Achievement*

*Algebraic knowledge pretest.* At the beginning of the semester, a pretest was administered to all students. The pretest consisted of the departmental Diagnostics test on the Intermediate Algebra knowledge with 20 multiple choice items. Because of the nature of developmental mathematics classes, it was expected that the students were already exposed to some topics before in the high school setting or the previous Elementary/Introductory and Intermediate classes. It was assumed that none of the questions from the pretest would appear alien to students, but students' skills were limited. It was designed to measure baseline student knowledge as they began Intermediate Algebra instruction. The test was administered to students during one class period (i.e., 55 minutes), before the introduction of any new course content and before any formal training with GC began. To simplify scoring, all items on the pretest were graded as either "correct" or "incorrect", with 10 points awarded for a correct solution and zero points awarded for incorrect solutions (i.e., total of 200 points possible).

*Algebraic knowledge posttest.* At the end of the semester, a 27-item, non-multiple choice final exam was administered to the remaining 18 students. The exam was designed by the mathematics department at the CCBC-Essex and was administered to all students enrolled in Intermediate Algebra. The posttest items were graded differentially with total possible points of 200. The final exam is cumulative and presents topics covered by Intermediate Algebra. Some of topics presented in the final exam and covered by the intervention are: functions and relations (their domain and range, graphs), solving quadratic equations, and graphing of functions (quadratic, exponential, logarithmic).

*Measurement of Students' Attitude toward GC*

A pre/posttest survey was used as an instrument designed to assess students' attitudes toward the use of GC in mathematics learning. The instrument being used is the Attitudes toward Graphing Calculators (GC) in Mathematics Learning Questionnaire (Reznichenko, 2007). It is a survey questionnaire made up of 23 items (Appendix B). The instrument is described as the following:

> It was developed to assess students' attitudes to the capabilities of GC to enhance understanding and learning of mathematical concepts and theories. Particular attention

was given to explorations and scientific visualizations to ensure that GC plays a pivotal role in reaching the learning outcomes.

The proposed instrument measures attitude from the subscales of cognitive and affective components. Cognitive attitude refers to beliefs or knowledge about GC and its capabilities. Affective attitude refers to feelings about GC. A Likert scale questionnaire is used to measure students' cognitive and affective attitudes when using GC in mathematics learning. All items use a 5-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree).

The items in the instrument are divided into four groups. The first two groups measure cognitive attitudes including GC competency (items 1 to 11) and usefulness of GC (items 12 to 15). The second two groups measure the affective attitudes including enjoyment of using GC (items 16 to 19) and anxiety in using GC (items 20 to 23). Items 1, 7, 8, 9, 11, 16, 17, 18, 19 explore students' positive attitudes. Items 2, 3, 4, 5, 6, 10, 12, 13, 14, 15, 20, 21, 22, 23) explore students' negative attitudes.

Based of the results of the pilot study, the instrument was reported (Reznichenko, 2007) as reliable with a high Cronbach's alpha coefficient for the cognitive attitude scale equal to 0.91 and for the affective attitude scale equal to 0.87. It was assumed that the instrument has good internal consistency reliability and it can be used to examine the attitudes toward GC in mathematics learning.

## Data Analysis

### *Analysis of Student Achievement*

A statistical paired t-test (one-tailed) comparing pretest/posttest scores was conducted to measure the effect of GC on student achievement in Intermediate Algebra class. The results of the pretest and the posttest for the Intermediate Algebra are shown in the Table 1.

Table 1

Intermediate Algebra Pretest to Posttest Results

| Sample Size | Pretest Mean | Posttest Mean | Difference Mean | P-Value |
|---|---|---|---|---|
| 18 | 26.6667 | 133.8889 | -107.2222 | .655 |

Therefore, there is a significant gain in student achievement in Intermediate Algebra class with the use of GC. The questions most often answered correctly were on the topics covered during intervention.

*Analysis of Student Attitude toward GC*

A paired t-test (one-tailed) comparing pre/post survey results was conducted to determine the effect of GC on student attitude toward GC in Intermediate Algebra class. The results of the pre-survey and the post-survey for the Intermediate Algebra are shown in the Table 2.

Table 2

Intermediate Algebra Pre-survey to Post-survey Results

| Sample Size | Pretest Mean | Posttest Mean | Difference Mean | P-Value |
|---|---|---|---|---|
| 18 | 82.2222 | 98.8889 | -16.6667 | <.0001 |

Therefore, there was a gain in student attitude toward GC in Intermediate Algebra class with the use of GC. This gain does not appear to be significant due to initially high results of some students shown on the pre-survey (maximum 107 out of possible 115).

## Summary

The results of the presented intervention show that there is significant gain in student achievement and a gain in student attitude toward GC in Intermediate Algebra class with the use of GC. Therefore, it can be concluded that the proposed intervention of implementing of GC in the teaching of developmental mathematics is successful.

GC not only allows the students and teachers more freedom to work together, but it also enables them to spend less time on redundant tasks and allows more time to be spent with exploration of the concepts. This is especially important when working with adults in developmental mathematics at the community college level.

GC implementation, such as the one described, may be an appropriate vehicle to prepare students for the workforce in the 21st century and to improve the state of mathematics education in the U.S.

# Appendix A

## Survey Collaborative

### Survey on Using Graphing Calculators (GC) in Mathematics Instruction

The following statements refer to your beliefs about GC in teaching of mathematics.
Choose one from the following five-point scale:
1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

| # | Questions | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| X | Part 1<br>Numerical, graphics, and programming/link capability of GC: | X | X | X | X | X |
| 1 | Allows all students access to important and useful mathematics. | | | | | |
| 2 | Enables teachers and students to concentrate on big mathematical ideas. | | | | | |
| 3 | Fosters the representation of mathematical concepts in multiple ways: numeric, symbolic, and graphical. | | | | | |
| 4 | Allows the investigation of rich applied problems that involve large amounts of data. | | | | | |
| 5 | Promotes the development of flexible ways to solve mathematical problems. | | | | | |
| 6 | Promotes students’ transition from procedural to conceptual knowledge. | | | | | |
| X | Part 2:<br>GC positively effect students’ skills in the following ways: | X | X | X | X | X |
| 7 | Concentration on the problem-solving process. | | | | | |
| 8 | Gain access to mathematics beyond the students’ level of computational skills. | | | | | |
| 9 | Explore, develop, and reinforce concepts including estimation, computation, approximation, and properties. | | | | | |
| 10 | Experiment with mathematical ideas and discover patterns. | | | | | |
| 11 | Perform those tiresome computations that arise when working with real data in problem-solving situations. | | | | | |
| 12 | Remember to cover the necessary basic skills to understand the mathematics being used with the calculator. | | | | | |
| X | Part 3<br>Your opinion: | X | X | X | X | X |
| 13 | There is need for implementation of GC in teaching Algebra | | | | | |
| 14 | I would implement GC in teaching Algebra | | | | | |
| 15 | My comments for implementation of GC in teaching Algebra<br>________________ | | | | | |

Appendix B

Attitudes toward graphing calculators (GC) in mathematics learning questionnaire

The following statements refer to the way you feel about GC in learning of mathematics. Choose one from the following five-point scale:

1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, 5 = strongly disagree.

| # | Question | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| 1 | Computing power makes it easier to explore mathematical ideas | | | | | |
| 2 | I know GC is important but I don’t feel I need to use it to learn mathematics | | | | | |
| 3 | GC is good tools for calculation, but not for my learning of mathematics | | | | | |
| 4 | I think using GC is too new and strange to make it worthwhile for learning mathematics | | | | | |
| 5 | I think using GC wastes too much time in the learning of mathematics | | | | | |
| 6 | I prefer to do all the calculations and graphing myself, without using GC | | | | | |
| 7 | Using GC for the calculations makes it easier for me to do more realistic applications | | | | | |
| 8 | I like the idea of exploring mathematical methods and ideas using GC | | | | | |
| 9 | I want to get better at using GC to help me with mathematics | | | | | |
| 10 | The symbols and language of mathematics are bad enough already without the addition of GC | | | | | |
| 11 | Having GC to do routine work makes me more likely to try different methods and approaches | | | | | |
| 12 | I don’t have any use for GC on a day to day basis | | | | | |
| 13 | I don’t think GC will be useful to me in my future job | | | | | |
| 14 | Anything that GC can be used for, I can do just as well some other way | | | | | |
| 15 | I don’t see how GC can help me to learn some new skills | | | | | |
| 16 | I enjoy using GC in mathematics activities | | | | | |
| 17 | GC is interesting, fascinating and easy to use | | | | | |
| 18 | I enjoy investigating mathematics problems using GC | | | | | |
| 19 | GC is very interesting and challenging to use | | | | | |
| 20 | I don’t feel comfortable when I learn mathematics using GC | | | | | |
| 21 | The thought of using GC in mathematics activities frightens me | | | | | |
| 22 | I am worried about using GC because I do not know what to do if something goes wrong | | | | | |
| 23 | The use of GC confuses me | | | | | |

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