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# THE EFFECT OF THE TEXAS INSTRUMENT INTERACTIVE INSTRUCTIONAL ENVIRONMENT ON THE MATHEMATICAL ACHIEVEMENT OF ELEVENTH GRADE LOW ACHIEVING STUDENTS

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**ABSTRACT**

Teaching and learning mathematics with technology poses a unique dilemma. If technology is to enhance mathematical achievement (NCTM, 2000), why do documented studies indicate that this may not be the case (Waxman, Connell, & Gray, 2002)? This study looks at the learning environment used when teaching with technology. What in the instructional environment actually maximizes technology's ability to increase mathematical achievement? The instructional environment used with Texas Instrument InterActive software is examined to determine its affect on the mathematical achievement of eleventh grade at-risk students when studying quadratic functions. The Texas Instrument instructional environment uses technology to manipulate mathematical objects to observe patterns, make generalizations, and test conjectures. Technology is used as a tool to perform action on objects and to problem solve.

## INTRODUCTION

In today's world, technology is essential in teaching and learning mathematics (National Council of Teachers of Mathematics, 2000). The technology influences the mathematics that is taught and enhances students' learning, but not all technology driven learning environments lead to a better understanding of




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mathematics (Waxman et al., 2002). Determining how best to teach and learn using technology are important areas of interest that address the growing emphasis on technology driven instruction in the mathematics classroom.

One of technology's strengths lies in its ability to support fluid inquiry where students can try various inputted values to observe patterns encouraging students to conjecture, predict, test, and generalize. The learning process, according to Kolb (1984), often begins with a person carrying out a particular action and then, seeing the effect of the action in the given situation, understands the effects in the particular instance in such a way that if the same action was taken in the same circumstances it would be possible to anticipate what would follow from the action. In this pattern the third step would be understanding the general principle under which the particular instance falls. When the general principle is understood, the last step, according to Kolb, is its application through action in a new circumstance within the range of generalization. Kolb (with Roger Fry) created his famous model out of four elements: concrete experience, observation and reflection, the formation of abstract concepts, and testing in new situations. Two aspects can be seen as especially noteworthy in a technology based environment: the use of concrete, "here-and-now" experience to test ideas; and use of feedback to change practices and theories (Kolb, 1984, pp. 21-22). Both aspects are supported by the interactive capabilities of technology where change, exploration, and instantaneous feedback are possible.

Heid (2003) suggests that the connection between a technology enhanced mathematical object and conceptualization may lead to greater understanding as oppose to using technology to learn process. For example, students who have a process understanding of a mathematical concept think of the concept only in terms of a procedure. Such students possessing only a process understanding of function might think of a function only in terms of a rule for obtaining output values. They would recognize $f(x) = 3x + 4$ as multiplying an input value by 3 and adding 4, and might not acknowledge the linear nature of the function, its use in predicting trend, the rate of increase and starting point of a given relationship, how the relationships changes when the starting point changes, etc. (Davis, 1979). In contrast, an object understanding of functions would enable one to operate on functions as entities, compose two functions, and think of the result as another function. By allowing students to directly manipulate such mathematical entities as variable expressions, function rules, and equations, technology gives access to the tools of mathematics and serves to provide students a deeper understanding of the objects on which the tools operate (Heid, 2003). With the emphasis on conceptualization rather than following procedures more emphasis can be put on problem solving, conjecturing, reasoning, predicting and making connections, all the foundational principles for mathematical learning (NCTM, 2000).

According to Shaffer and Kaput (1999) a computer based instructional environment should strive to give students fluency in varieties of representational systems, provide opportunities to create and modify representational forms, develop skill in making and exploring virtual environments, and emphasize mathematics as a fundamental way of making sense of the world. Multiple representations are a powerful visual way of showing patterns (Pinker, 1997), and patterns are the building blocks of mathematics (AMS, 2005). Wilhelm, Confrey, Castro-Filho, and Maloney (1999) indicate that through the use of technology, which enables linked, multiple representations, students may learn crucial algebra concepts quicker and in more depth. Heid (2001) suggests that the use of the computer facilitates and promotes use of multiple representations in the learning of functions. Since algebra concepts, such as functions, serve as a gatekeeper to high school graduation and college admission (U.S. Department of Education, 2003), a technology enhanced instructional environment that supports a more comprehensive understanding of algebra and functional relationships is worthy of further study.

The capabilities of TI InterActive software, a Texas Instruments program that creates an interactive computer environment with TI graphing calculator functionality, provides a format for developing mathematical objects that when manipulated develop patterns that can lead to deeper understanding of mathematical concepts. In this study Texas Instruments InterActive instructional environment was examined to determine what affect it had on the mathematical achievement of eleventh grade at risk students when studying quadratic functions.

## METHODOLOGY

### Research Design

A quasi-experimental pretest-posttest control-group research design was used to test the hypothesis of the study. The use of the 2004 and 2006 Texas Assessment of Knowledge and Skills Grade 10 Mathematics Test scores as the covariate allowed posttest differences rather than initial differences to be attributed to treatment differences not extraneous variables. The independent variable was the use or non-use of Texas Instruments InterActive instructional environment while studying quadratic equations. The dependent variable was mathematical achievement as measured by Objective 5, Quadratic Functions, on the Texas Assessment of Knowledge and Skills Exit Level Mathematics Test (2005 and 2007).

### Participants

Participants came from two large metropolitan area school districts in Texas. The study used seven teachers, three from one district and four from the other. The 19 classes and 95 students were separated into experimental and control groups. Ten classes were in the experimental group and nine classes in the control group. Forty-eight students were in the experimental group, and 47 students in the control group. To qualify for the study students had to be an at-risk eleventh grade Mathematic Models with Application student, attend at least six of the eight lessons on Quadratic Functions, and take the Exit Level Texas Assessment of Knowledge and Skills. Participants were classified as at-risk by their respective districts. Both groups averaged approximately five student participants per class that qualified for the study. The classes ranged in size from 10 to 24 students. The experimental group's class size averaged 15 students, where the control group averaged 18 students (see Table 1).

## Instrumentation

The dependent variable, mathematical achievement, was measured by using Objective 5, Quadratic Functions, scores from the Texas Assessment of Knowledge and Skills Exit Level Mathematics Test. The covariate was determined by using the Texas Assessment of Knowledge and Skills Grade 10 Mathematics scores for Objective 5, quadratic functions. The scores range from 0 to 5, 5 being the highest possible score. These instruments are criterion-referenced and have been administered since 2003. The TAKS Exit Level Test for Mathematics and TAKS Grade 10 Mathematics Test were chosen because they are both criterion-referenced, and because of the test's potential impact on students' graduation, and school and school districts accountability.

Content validity for both instruments was reviewed each year and included an annual educator review, revision of all proposed test items before field-testing, and a second annual educator review of data and items after field-testing. In addition, each year panels of recognized experts in the fields of mathematics meet in Austin to critically review the content validity of each of the high school level TAKS assessments to be administered that year. This critical review is referred to as a content validation review and is one of the final activities in a series of quality-control steps designed to ensure that each high school test is of the highest quality possible. For internal consistency, the Kuder-Richardson Formula 20 was used with reliabilities in the .80s and .90s (Texas Education Agency, 2007). Internal consistency and standard error of measurement specifically for Objective 5 were not available from the Texas Education Agency.

## Treatment

The Experimental Group received instruction on quadratic functions in the computer lab using the features of Texas Instruments InterActive instructional environment. In the instructional environment, supported by Texas Instruments InterActive software, technology's main function was to develop the concept, not to reinforce or provide practice in a different modality. Texas Instruments

Table 1. Participants by Teacher and Group

| | | Experimental group | | | | | Control group | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Teacher | Class | Senior | Spec. ed. | DNQ* | Tested | Total | Senior | Spec. ed. | DNQ* | Tested | Total |
| A | 1 | | | | | | 3 | 1 | 4 | **3** | 11 |
| | 2 | 3 | 1 | 1 | **5** | 10 | | | | | |
| B | 1 | | | | | | 3 | — | 5 | **9** | 17 |
| | 2 | 4 | — | 3 | **6** | 13 | | | | | |
| | 3 | 5 | 3 | 5 | **4** | 17 | | | | | |
| C | 1 | | | | | | 4 | — | 7 | **9** | 20 |
| | 2 | 5 | — | 4 | **4** | 13 | | | | | |
| | 3 | 6 | — | 3 | **3** | 12 | | | | | |
| F | 1 | 4 | — | 4 | **6** | 14 | | | | | |
| | 2 | 5 | — | 6 | **3** | 14 | | | | | |
| | 3 | 2 | — | 4 | **7** | 13 | | | | | |
| | 4 | 4 | — | 6 | **5** | 15 | | | | | |
| | 5 | 11 | — | 8 | **5** | 24 | | | | | |
| G | 1 | | | | | | 12 | — | 3 | **2** | 17 |
| | 2 | | | | | | 12 | — | 3 | **6** | 19 |
| | 3 | | | | | | 13 | — | 2 | **4** | 19 |
| H | 1 | | | | | | 12 | 1 | 5 | **6** | 24 |
| | 2 | | | | | | 9 | 1 | 3 | **6** | 19 |
| I | 1 | | | | | | 12 | | 5 | **1** | 18 |

*Did Not Qualify (excessive absences, did not take TAKS Test).

InterActive software's ability to generate fluency, create and modify representational forms is used to develop the dimensionality of a quadratic function through exploration, problem solving, and through making and exploring virtual environments.

In five of the six lessons, students manipulate an interactive graph and table by changing inputted values using a slider or interactive math box. Within seconds multiple graphs are created by increasing and decreasing the value on the slider. Explorations are guided by questions directing students' attention to the changes on both the graph and table. On the same screen as the graphs, students type in their responses to the questions. Following each exploration activity a graph with given, stationary points are displayed and students are asked to enter a value for the variable that alters the equation and changes the corresponding parabola to include all the given points. During the elaboration phase of instruction students apply the patterns they discovered in a different setting. Again they know they can adjust any answer, and test conjectures. The cycle of engage, explore, explain, and elaborate is found in five of the six lessons, but the primary feature of each activity in the lessons is the manipulations of mathematical objects that take on new dimensions of meaning with each activity.

For eight days of instruction the Experimental Group spent 55 minutes a day in the computer lab working on six lessons designed by the researcher. Lessons followed the Texas Essential Knowledge and Skills (TEKS) for quadratic functions. Graphing calculators, a familiar tool and part of the regular learning environment for the students, were available for their use. As shown in Table 2, only a minimal amount of time was spent using the calculators. Students were encouraged to discuss their strategies and results with each other.

The Control Group received instructions for quadratic functions using the same scope and sequence but was instructed using a format designated by the district that includes lecture, notes, drill, and guided practice. The students were likewise encouraged to discuss their strategies and results. All lessons followed the Texas Essential Knowledge and Skills (TEKS) objectives on quadratic functions, the same objectives followed by the Experimental Group. The supporting technology consisted of the availability and use of graphing calculators. The Control Group used graphing calculators to graph quadratic equations and record the table values. Unlike the Experimental Group these students stayed in intact classrooms and did not go to the computer lab which was in a different hallway.

## Learning Environment

To further compare and contrast the two groups' learning environment the lessons were analyzed using Bloom's Revised Taxonomy to determine the cognitive processing domains best suited to the activities used in each group. The results are shown in Tables 2 and 3.

Table 2. Experimental Group Lesson Plans, Bloom's Revised Taxonomy

| Experimental group lesson plan | Remembering | Understanding | Applying | Analyzing | Evaluating | Creating |
|---|---|---|---|---|---|---|
| ***Change the values*** until you discover the effect of "v," "h," and "a" on the graph and set of points. ***(Activity 1-3)*** | | | | x | x | |
| Generate vertex and symmetrical points from the given quadratic equations. ***(Activity 1-3)*** | | | | x | x | |
| Generate a function that would include points on a scatter plot. ***(Activity 1-3)*** | | | | x | x | x |
| Apply quadratic functions, their graph and table of values, in real life situations. ***(Activity 4)*** | | | x | | | |
| Explore finding solutions to quadratic function by creating a graph and finding the intercepts. Justify your answer algebraically. ***(Activity 5)*** | | | | x | x | |
| Create two equations that share the same axis of symmetry. Create two equations that share the same maximum point. Create two equations that share the same minimum point. Create two equations that share the same vertex point. Create two equations that share the same x-intercept. ***(Activity 6)*** | | | | | | x |

The cognitive thinking skills required of the Experimental Group are more complex and demanding than that of the Control Group. Conjecturing and problem solving characterize the activities found in the Experiment Group because the cognitive components are based on exploration, investigation, and the generative ability of the technology. In the Control Group more time was spent on repetitive activities with directions that ask the same question, where limited thinking and

Table 3. Control Group Lesson Plans,
Bloom's Revised Taxonomy

| Control group lesson plan | Remembering | Understanding | Applying | Analyzing | Evaluating | Creating |
|---|---|---|---|---|---|---|
| Graph the function linear and quadratic, make table, describe (11)* *Graphing Calculator used* | x | x | x | | | |
| Match symmetric pairs of points, table, graph, equation, vertex (8 matches) *Graphing Calculator (opt.)* | x | x | | | | |
| Find vertex, describe changes (8) *Graphing Calculator used* | x | x | | | | |
| Write an equation for each graph (5) *Graphing Calculator used* | | | x | | | |
| Fill in shift, vertex, axis of symmetry, and graph, fill out table (12)* *Graphing Calculator used* | x | x | x | | | |
| Describe transformation (12) | x | x | | | | |
| Sketch the graph (8)* *Graphing Calculator used* | | x | | | | |
| Circle the equation that matches the graph (8) *Graphing Calculator used* | x | x | | | | |
| Complete table and graph (11)* *Graphing Calculator used* | x | x | | | | |
| Name points where crosses x axis, give solutions | | x | x | | | |

*For 42 problems graphing and making a table are actions to be taken. Though the graph and table are viewed on the graphing calculator, students are asked to transfer that information using paper and pencil. A major focus of these activities is to record information from the graphing calculator.

recording given information rather than processing information occur. In both groups technology was used, but used differently. The Experiment Group focused on experimenting with the generated information to find predictable patterns that could be applied, then making conjectures and testing them, where the Control Group focused more on graphing skills with the graphing calculator used as a tool to access the data used to graph, make tables, and reinforce answers. Based on the number of problems (42) devoted to finding and recording specified graph and table data, technology was used more by the Control Group to create graphs and tables than to drawing conclusions based on testing conjectures through trial and error. The Control Group focuses on repeated practice rather than on problem solving.

## Fidelity of Treatment

In order to insure treatment fidelity teachers' lesson plans and the official student records were used to verify that: 1) students in both Experimental Group and in the Control Group were in attendance for at least six of the eight instructional sessions; 2) students in the Experiment Group received instructions as stated above; and 3) students in the Control Group did not receive instruction in Texas Instruments InterActive instructional environment and that instructions followed the district suggested lesson plans.

Students were asked to keep a journal of their experiences and observations when using the TI InterActive instructional environment to assure fidelity of treatment and verify a problem solving environment was being maintained. The observations are shown in Table 4 as quotes from four students in the Experimental Group.

To further insure fidelity of treatment and verify that an effective computer learning environment, according to Shaffer and Kaput (1999), was maintained while using Texas Instruments InterActive instructional environment, observations were made using Schoenfeld's (1985) time line analysis protocol format for problem solving.

Schoenfeld's time line analysis protocol format for problem solving entailed observing activities involved in problem solving, and recording the time span of the activity as a line segment on a time line indicating when the activity began and when it ended. The time line was used to analyze the sequencing and frequency of the problem solving processes.

Five students from three classrooms were observed for a block of eight minutes as they worked on Lesson Two of the Texas Instruments InterActive instructional environment activity. The sequencing of activities indicated that students in the Experimental Group cycled through the problem solving process at least four times during eight minute blocks of time. "Fluency in varieties of representational forms," was observed as students in the Experimental Group had the "opportunity to create and modify representational forms" (Shaffer & Kaput,

Table 4. Journal Entries

| Student quote | Observation |
|---|---|
| Abby (fictitious name), "**We worked together and noticed a pattern which helped us.**" | TI InterActive instructional environment stimulated collaborative work. Students were able to discuss their observations and conjectures about the patterns they saw as they manipulated objects. Students found the patterns helpful in drawing conclusions and making decision to reach their desired goal, whether that meant finding the right equation for a graph or determining why the graph moved right when a negative value was entered into the equation. |
| "**It was like hands on and we got to watch the graph change as we changed the numbers,**" Abby. | The instantaneous feedback reinforced the relationship between inputted number and the graph. The software allowed a tactile sense of control where the student was in charge creating a resulting behavior by initiating action on a value or expression. |
| Abby responding to what she thought was significant about the experience by writing, "**I got to watch instead of trying to do it in my head.**" | She felt more confident in manipulating a visual object when initially learning a concept than the manipulation of a mental object, which fits the developmental model espoused in the Action on Objects framework where a visual manipulative object should be used before a mental object evolves. |
| Ben, a fictitious name, recorded in his journal the following entry: "**We had to make assumptions on what 'a =' to get the parabola lined up with the points.**" | Looking at the results of choices made, lead to conjectures and assumptions as how to manipulate the 'a' value to get the desired results. The processing of information rather than regurgitating back given steps implies a higher level of thinking is involved in the decision making. |
| Ben noticed, "**I was able to see what exact number is necessary to line them up.**" | Correctness was not seen as a right or wrong answer, but the fulfillment of a conceptual relationship. The relationship between the number choice and lining up the graph with its given points was the desired response and students could immediately see their action resulting in the desired object relationship. |

Table 4. (Cont'd.)

| Student quote | Observation |
|---|---|
| "**The capability of seeing the parabola change allowed me to grasp how the positive and negative numbers affect it,**" Ben wrote in his journal entry. | The learning process when using TI InterActive instructional environment is not linear. Dealing with incorrect answers is not seen as a distraction, or a sign of defeat, it is part of the process. The emphasis is noticing change and the predictability of actions on given objects. |
| Ben noticed, "**I was able to visually see the changes. Sight is the best way for me to learn.**" Corey said, "**It was easy having moving visual.**" | The process is seen as active, alive, changing and growing, one in which student involvement is essential. Students are not seen as passive receptors of steps and procedures to be memorized and followed explicitly. Visually seeing the change and seeing it quickly through the use of technology enhances and reinforces basic patterns. |
| Corey, responding to what he did and thought that led him to a better understanding of quadratic functions responded, "**By being able to move the graph to see what it could do at different numbers [I was able to better understand quadratic functions].**" | The interactivity or "moving" capability of the software reinforces the process nature of mathematical thought. It is interesting to note that Corey did not actually move the graph. By inputting certain values in to the designated cell this action caused the graph to move, but in his mind he was moving the graph. The close bond between action and object is seen in this example. |

1999) using Texas Instruments InterActive instructional environment. In the Control Group students were not being asked to explore or conjecture and the problem solving model could not be utilized. The objective in the Control classroom was to find the corresponding table, symmetric pairs of points, vertex, and graph which most students did by matching points on the graph; no conjecturing or inquiry was needed.

Schoenfeld's (1985) time line analysis protocol format for problem solving was also used to determine how much time, and the percent of the total time, spent on "making and exploring the virtual environment" (Shaffer & Kaput, 1999). Before attempting the timeline it was determined that two actions could be occurring simultaneously or very close to it. For example, a student could be talking, discussing his plan and also manipulating the slider. The results shown in the Table 5 indicate that 51% of the time was spent on actively manipulating

Table 5. Time Task Analysis of Five Students

| Activities | A | B | C | D | E | Total | % of time[a] |
|---|---|---|---|---|---|---|---|
| Understand/Devise a Plan | | | | | | | 48% |
| • Read direction | .75 | 1.75 | 1 | .75 | .5 | 4.75 | |
| • Discuss what needs to be done | 5.25 | 4.25 | 3.75 | 4 | 6 | 14.25 | |
| Carry Out Plan/Actively Manipulate Objects | | | | | | | 51% |
| • Attempt a problem/change slider | 2.5 | 3 | 1 | 3.75 | 2 | 12.25 | |
| • Use calculator | — | — | .5 | 1 | .75 | 2.25 | |
| • Explore by attempting another problem | — | 4 | — | — | 1.75 | 5.75 | |
| Look Back/Conjecture Problem Solving | | | | | | | 43% |
| • Make conjecture | — | — | .5 | .25 | — | .75 | |
| • By looking back, draw a conclusion, generalization | 2.25 | 1.25 | — | 2.25 | 2 | 7.75 | |
| • Use generalization to show understanding | 1 | 1 | 1.75 | — | .5 | 4.25 | |
| • Type in answer | — | — | 4 | — | .5 | 4.5 | |

[a]% of time reflects that different activities could be occurring at the same time.

objects, or "making and exploring the virtual environment." Forty-three percent of the time was spent on conjecturing and problem solving and 51% was spent on preparation and devising a plan. The percentages indicate that more than one activity could be occurring at the same time.

Table 5 serves to document the fidelity of treatment as measured by Schoenfeld's time line and verifies that an effective computer learning environment was created.

## Data Collection Procedure

Following approval by the Committee for the Protection of Human Subjects at the institutions involved, the data were obtained by the researcher from the teachers. The teachers assigned each student a number. For the first study of data, the April 2005 Objective 5, Quadratic Functions, scores from the Texas Assessment of Knowledge and Skills Exit Level Mathematics Test; and, the April 2004 Objective 5, Quadratic Equations, scores from the Texas Assessment of Knowledge and Skills Grade 10 Mathematics Test were accessed by the teachers through the district's secure electronic assessment Web space for the participants. Scores were recorded indicating the class they attended, whether attendance requirements had been met, whether the student was in the

Experimental Group or Control Group and if they were classified by the district as at-risk of failing. No personal identifiers were used. The second collection of data occurred two years later with the April 2007 Objective 6, Quadratic Functions, scores from the Texas Assessment of Knowledge and Skills Exit Level Mathematics Test, and the April 2006 Object 5, Quadratic Equations, scores from the Texas Assessment of Knowledge and Skills Grade 10 Mathematics Test accessed by district personnel to recorded needed data. The same data were collected as well as ethnicity, gender, and whether they were classified as Limited English Proficient (LEP).

### Data Analysis Procedures

The data collecting using the procedures described in the previous section were analyzed using Analysis of Covariance procedures in which the dependent variable was mathematical achievement as measured by Objective 5, Quadratic Functions, on the Texas Assessment of Knowledge and Skills Exit Level Mathematics Test (April 2005 and April 2007) by the posttest. The covariate was mathematical achievement as measured by Objective 5, Quadratic Functions, on the Texas Assessment of Knowledge and Skills Grade 10 Mathematics Test (April 2004 and April 2006). The 95% confidence level ($p < .05$) was the criterion for determining statistical significance. The criterion level for educational significance was one-third a standard deviation ($d = 0.33$) (Cohen, 1988).

### Limitations

The method of selecting the sample may not have produced a random sample. Hence, there may be a selection problem. All Mathematics Models with Application students at each high school were used to minimize this risk. The limited number of participants may have jeopardized the validity of the test and its generalizability, yet the target group for this study is small but significant as to a school's accountability according to "No Child Left Behind" legislation.

## RESULTS

The research question addressed in this study stated: What is the effect of the Texas Instruments InterActive instructional environment on the mathematical achievement of eleventh grade low achieving students when studying quadratic functions? In addressing this research question the study tested the following directional research hypothesis based on previously mentioned research: The mathematical achievement of eleventh grade low achieving students when studying quadratic functions who use Texas Instruments InterActive instructional environment, which includes constructive teaching strategies, is statistically significantly greater than the mathematical achievement of eleventh grade low achieving students when studying quadratic functions who do not use Texas

Instruments InterActive instructional environment, but use a traditional lecture, notes, drill, and practice approach.

The results from the Means Table (see Table 6) deserve a closer look.

Upon visual inspection of means shown a potential significant difference is noticed with 3.21 as the mean for the Experimental Group and 2.25 as the mean for the Control Group. The standard deviations, also found in the descriptive statistics, are close in value (1.13, 1.30) indicating similar patterns of deviation which strengthens the argument for use of an Analysis of Covariance.

The Analysis of Covariance shows the group was statistically significant with a $F(1, 95) = 11.56$, $df = 1$, and $p \leq .001$ and et al. = .112.

The Levene's Test of Equality of Error Variances, which tests the null hypothesis by determining if the error variance of the dependent variable is equal across groups, $F(1, 95) = .792$, $p = .376$, showed that it was not statistically significant, therefore, the equality of variance consideration is not ruled out (see Figure 1).

To summarize, the adjusted mean obtained for the Experimental Group (3.21) was statistically significantly higher than the adjusted mean obtained for the Control Group (2.42), and the significant differences in adjusted means are attributed to the posttest variances between groups. Therefore, the directional research hypothesis is accepted.

## Interpretation

The mathematical achievement of eleventh grade low achieving students when studying quadratic functions who use Texas Instruments InterActive instructional environment is statistically significantly greater than the mathematical achievement of eleventh grade low achieving students when studying quadratic functions who do not use Texas Instruments InterActive instructional environment, but use a traditional lecture, notes, drill, and practice approach. Indeed, inasmuch as the obtained effect size ($d$ = + 0.68) is over + 0.33, it can also be argued that the difference favoring the students who used Texas Instruments InterActive instructional environment is educationally significant. The Texas Instrument InterActive

Table 6. Means Table

| Group | *N* | Pretest Mean | Pretest *SD* | Posttest Mean | Posttest *SD* | Adjusted mean | *d* |
|---|---|---|---|---|---|---|---|
| Experimental | 48 | 2.46 | 1.09 | 3.21 | 1.13 | 3.21 | +0.68 |
| Control | 47 | 2.46 | 1.12 | 2.25 | 1.30 | 2.42 | |
| Total | 95 | 2.46 | 1.10 | 2.82 | 1.27 | | |

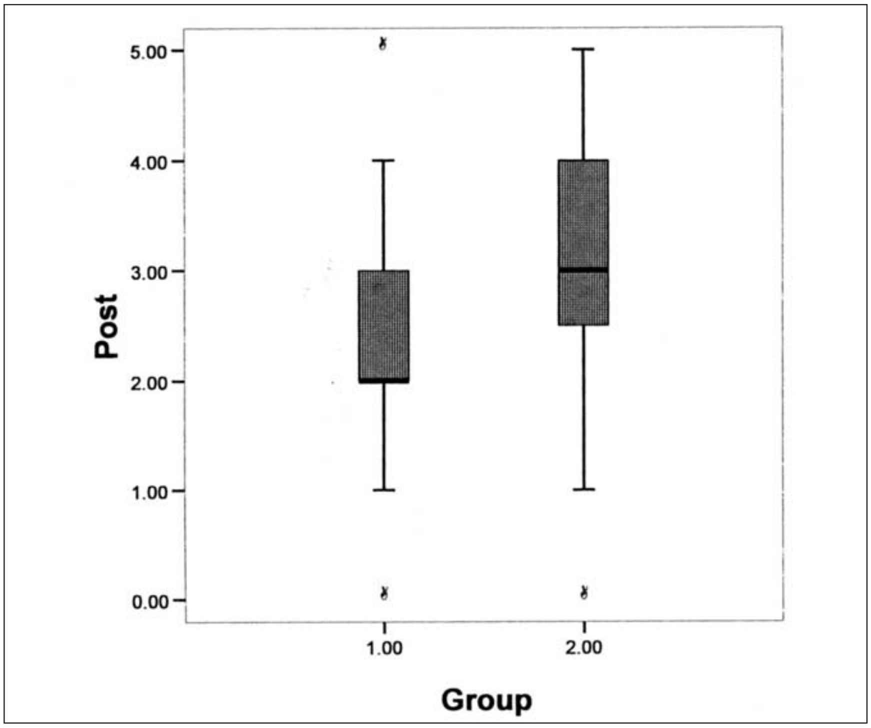


Figure 1. Estimated marginal means of posttest.

instructional environment then, according the findings of this study, facilities the conceptualization of quadratic functions concepts for eleventh grade at-risk high school students enrolled in Mathematics Models with Application class as demonstrated by performance on the Texas Assessment of Knowledge and Skills Exit Level Mathematics Test.

## Implications

The results of this study strongly suggest that using Texas Instruments InterActive instructional environment when teaching quadratic functions with at-risk eleventh grade students increases mathematical achievement on Objective 5, quadratic functions, of the Texas Assessment of Knowledge and Skills Exit Mathematics Test. It can be implied from this study that if improvement occurs using Texas Instruments InterActive instructional environment for at-risk eleventh grade high school, students who struggle with quadratic functions could benefit from this learning environment.

The implications inherent in this study suggest the results are deeply embedded in the core of the learning process and the necessity to create an environment that involves all students in high level thinking skills and to promote problem solving versus a more drill-practice approach. Technology, it could also be implied, should be used to create environments for higher cognitive domains, for problem solving and conjecturing, to assure student success.

The results of this study imply that the instructional environment used creates objects that possess well-defined properties that allow the student to discover and explore a quadratic function's attributes as shown in different representations. Once redefined in rich mathematical context the function can be used in ways it was unable to be used in before. It is seen not as an output yielding process but as a rich pattern that is repeated in the world around us. The instructional environment enables creation of new objects that can be managed and manipulated to continue a cycle of development until concepts become reified, real, and useable.

Research based direction is offered to students who struggle with abstract algebraic concepts by giving them an opportunity to manipulate and explore various algebraic objects in a problem-solving environment where the emphasis is on conceptual development rather than following procedures. The action on object approach embodied within this environment enables learning functional relationships, problem solving, and developing mathematical thinking, and has the potential to reshape mathematical content. The findings of this study give credibility and importance to the actions on objects approach to learning when used in a technology driven learning environment.

## Recommendations for Further Study

Further research is needed to determine the potential and scope of Texas Instruments InterActive instructional environment. According to this research, the Texas Instruments InterActive instructional environment offers a positive and hopeful direction to follow, but more students need to be studied and other mathematical concepts like proportionality, linear relationships, limits, derivatives, and integrals should be explored using Texas Instruments software environment.

Research is also needed to determine how best to change the emphasis in the classroom from skill and process driven procedures to an "actions on objects" learning approach using technology driven mathematical objects. Which actions unique to technology enhanced learning environments lead to conceptual understanding? Which well defined objects can be used and how can they best be integrated into the curriculum? Which teaching practices would best support a technology enhanced learning environment? What role does communication play in a technology enhanced learning environment? Can technology be used in enhancing learning for all learners? Indeed, more research is needed to clarify technology's role in the learning environment and establish guidelines for effective use of technology in mathematics classrooms.

## Summary

As a result of this study, findings have revealed that the mathematical achievement of eleventh grade low achieving students when studying quadratic functions who use Texas Instruments InterActive instructional environment is statistically significantly greater than the mathematical achievement of eleventh grade low achieving students when studying quadratic functions who do not use Texas Instruments InterActive instructional environment, but use a traditional lecture, notes, drill, and practice approach. Thus, the analysis of the data indicates that the Texas Instruments InterActive instructional environment, when used appropriately to learn quadratic equations, can help eleventh grade Mathematics Models with Application students in the State of Texas to improve their Texas Assessment of Knowledge and Skills Exit Mathematics Test results in the area of Objective 5, quadratic functions. Implications and recommendations suggest that actions on objects framework, as used by the Texas Instrument InterActive instructional environment, could make mathematics accessible to more students and open new doors of mathematical understanding.

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