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The Effects of the Cognitive Tutor Algebra on Student Attitudes and Achievement In a 9th Grade Algebra Course

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THE EFFECTS OF THE COGNITIVE TUTOR ALGEBRA ON STUDENT ATTITUDES AND ACHIEVEMENT IN A 9TH GRADE ALGEBRA COURSE

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ABSTRACT

Since the emergence of instructional technology, there has been an emphasis to integrate technology into the classroom to support learning. However, few studies detail how well technology assists developmental-mathematics students. The purpose of this study was to compare and analyze achievement and attitude results of developmental-mathematics students who used a technology-based algebra program, the Cognitive Tutor Algebra (CTA) with a comparison group of average and above average learners in a traditional setting using an algebra textbook.

The study utilized a quasi-experimental design with nonequivalent control groups. The effects of the CTA program on achievement and attitudes were examined through a regression-discontinuity design with multilevel modeling of the dependent variables- the Achievement Levels Test (ALT), gender, a student's prior mathematics grade, English Language Learner (ELL) status, and scores from two scales from the Fennema-Sherman Mathematics Attitudes Scales (FSMAS).

Participants included all ninth-grade students enrolled in a first-year algebra course (N = 1027). Study groups include the treatment (CTA) classrooms (n = 33) and comparison classrooms (n = 36).

Hierarchical Linear Modeling (HLM) was used to address the possibility of classroom composition contributing to the achievement outcome. The HLM analysis showed the CTA program to have a non-significant, predictive relationship with student academic achievement as measured by ALT scores. Gender had a statistically significant positive relationship ($p \leq .01$) with student academic achievement, and ELL status had a statistically significant positive relationship ($p \leq .01$) with a gain in students' pre-posttest data. ELL status was the strongest predictor of student academic achievement gain as measured by the ALT scores.

There were too few students ($n = 127$) to address the possibility of classroom composition contributing to a change in student attitudes on FSMAS using HLM. The null hypothesis was not tested.

The study has implications for technology-based practices in the teaching of algebra with low-ability students.

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CHAPTER I

INTRODUCTION

Problem and its Context

> The continuing poor mathematical performance of our high school graduates across four decades and countless educational reforms suggest that the problem of mathematics education is far more intractable than the challenges of landing on the moon or decoding the human genome. (Steen, 2002, p. 6)

In 1957, the sudden and unexpected appearance of Sputnik galvanized America's resolve to improve mathematics and science education in order to win the space race to the moon. In the early 1960s, there was a renewed emphasis on science and mathematics education if America had any hopes of "catching up with the Russians." During the Sputnik era, mathematics was thought of as a subject for those with special talents. Fendel, Resek, Fraser and Alper (1997) contended that the ability to perform complex algebraic manipulations was once the hallmark of the mathematically literate. At a National Academy of Science forum Anthony

Carnavale observed that numeracy has always been about separation- "of rich from poor, of boys from girls, of elites from plebeians. Historically, failure in mathematics has been the biggest barrier to upward mobility in education " (as cited in Steen, 2002, p. 7).

Without regard to social status, the essence of mathematical literacy is the ability to use mathematical concepts to understand the world (Fendel, et al., 1997). However, the vision of equity in mathematics education challenges such a pervasive notion in North America that only some students are capable of learning mathematics (National Council of the Teachers of Mathematics, 2000). Because many states have increased mathematics standards to include concepts in algebra and geometry and have instituted high stakes testing as one exit requirement for high school graduation, it may become necessary to teach higher levels of mathematics to *all* students.

In 1983, the National Commission on Excellence in Education pointed to our nation's low performance in international studies as evidence that we were *A Nation At Risk*. In response to *A Nation at Risk*, numerous policy solutions were proposed and tried. School boards, state boards of education, and state legislatures dictated new regulations concerning school governance, the subjects that students must take, stronger teacher certification requirements, more homework, and longer school days. These reforms, however, failed to correct the problems, and some grew worse (Godwin & Sheard, 2001). Some scholars questioned whether or not the Commission's report was intended as a scholarly study on the plight of American education or if it was commissioned for another purpose.

In 1989, President Bush and the governors of all 50 states adopted the National Goals for Education. One goal stated that the United States will be "first in the world in mathematics and science achievement by the year 2000" (U.S. Department of Education, 2000, p. 10). However, The Third International Mathematics and Science Study (TIMMS) showed that our nation has not yet reached this mark. With data from a half-million students, the 1995-96 TIMMS was the largest, most comprehensive, and most rigorous international study conducted to that time. Students from 41 nations were tested in 30 different languages at three different education levels to compare their mathematics and science achievement (NCES, 1995). At the end of high school, U.S. performance was among the lowest in both science and mathematics and that included our most advanced students.

TIMMS 1999, which was a successor to the acclaimed 1996 study, focused on mathematics and science achievement of eighth-grade students. Thirty-eight countries participated in 1999 along with 27 jurisdictions from all across America including 13 states and 14 districts or consortia (NCES, 1999). The 1999 TIMMS results showed little change in eighth-grade mathematics achievement between 1995 and 1999. Five Asian countries led world-class performance levels in mathematics. The message of TIMMS continued to echo that our students were losing ground. Our fourth graders scored close to the international average in mathematics and science; our eighth graders scored slightly above the international average in science and slightly below the international average in mathematics (U.S. Department of Education, 2000).

Bracey (2000) disagreed that the TIMMS report was an accurate reflection on math and science achievement of American students. Bracey (2000) argued that "American students were mostly not age-mates of those [students] in other counties" (p.4). In the math and science literacy assessment, many students were up to three years older than the American sample. American students may have had up to three fewer years of math and science instruction than did students from other nations if one makes a direct comparison of student scores. This comparison was made by the American media with the assistance of the U.S. Department of Education. Achilles (2002) noted that information and opinions are plentiful for education leaders, but not all such information or opinion has equal value, validity, or even utility.

One excellent case in point is how testing the final year of secondary school (called "Population 3") created challenges for the TIMMS researchers. Because the final year of school varied across and even within countries, some students completed secondary school after a two-, three-, four-, or even a five-year program (Mullis et al., 1998). In addition, the U.S. Commissioner of Statistics, Forgione stated that "The purpose of this [Final Year] component of TIMMS was not to compare students of the same age or years of schooling, but rather to compare students at a similar point in the education system: the end of secondary school" (cited in Bracey, 2000, p.5).

However, the report entitled *Pursuing Excellence* (NCES, 1998, p. 24, bold in the original) contained misleading statements about the comparability of students who took the exams. The report stated:

> As is discussed in more detail in chapter 4, the most recent data indicated that in most counties participating in TIMMS secondary school, enrollment

> rates are similar to that of the United States. *Not only do the TIMMS countries have most of their secondary-age population enrolled in school, the strict quality controls discussed earlier ensured that the sample of students taking the mathematics and science general knowledge assessments were representative of the entire population at the end of secondary school*…This represents an improvement over previous studies of secondary school achievement, in which some countries only assessed students in certain types of schools or programs.

Bracey (2000) pointed out that though the counties did have *most* of their students in secondary school, *most* could mean as few as 77% as compared to 97% for the United States.

On the national front, the 1996 National Assessment of Educational Progress (NAEP) showed that fewer than one-third of all U.S. students in grades 4, 8 and 12 performed at or above the "Proficient" achievement level in mathematics and science, where "Proficient" represented solid academic performance for each grade assessment. Perhaps more alarming, more than one-third of U.S. students scored below the "Basic" level in these subjects, which means they lacked the mastery of the prerequisite knowledge and skills needed for "Proficient" at each grade (U.S. Department of Education, 2000). "Despite some improvements in NAEP mathematic scores since the 1970s, our students' performance in science and mathematics has remained at disappointing levels for nearly 30 years" (U.S. Department of Education, 2000, p.11).

However, one should exercise caution when interpreting NAEP results because average scores were derived using a complex sample design rather than from those of a simple random sample. Because conventional formulae for estimating sampling variability that assume simple random sampling were determined inappropriate, NAEP used complex sampling procedures, which resulted in a "jackknife replication procedure to estimate standard errors" (NCES,2001, p. 215). According to Johnson and Rust (as cited in NCES, 2001), "plausible values methodology can be used to describe the performance of groups and subgroups of students, but the underlying imprecision involved in this step adds another component of variability to statistics based on NAEP scale scores" (p. 216). Additionally, all assessments have some degree of uncertainty because items on the test are intended to be representative and not intended to be exhaustive of a particular area of content.

With respect to the quality of mathematics education in America, high school students must be adequately prepared for the workforce of tomorrow and be prepared to live productive lives. Knowledge of algebra is important for the workplace and for making intelligent decisions as members of society (Burrill, 1997). The ability to develop and interpret graphs, to work with formulae, to organize and analyze data, and to interpret the data is required in the workplace and in the home. Even student athletes are taught algebraic formulae that are used to rate quarterbacks' performance and to develop both defensive and offensive strategies (Burrill, 1997). However, Bogan (1997) claimed that students with poor academic performance are often marginalized by teachers as well as by their peers.

In many high schools, developmental-mathematics students are tracked into lower-level mathematics classes where concepts in algebra are not taught. Oakes (1995) argued that teachers of lower-level mathematics classes do not expose students to academic rigor, critical thinking or problem-solving skills and instead continue to focus on computation. Because states increased mathematics standards to include concepts in algebra and geometry and have instituted high stakes testing as one exit requirement for high school graduation, it will become necessary to teach higher levels of mathematics to all students. Because there has not been a wide body of research that involves students who are outside the mainstream of most school mathematics programs (Jitendra & Xin, 1997), in this study, the researcher investigated whether or not a technology-based algebra program used with high school freshmen who were identified as developmental-mathematics students is effective.

Mathews (2002) posited that in many parts of the country there is an aggressive effort to focus on algebra. He claimed that some school districts and one large state, California, want every student completing algebra, "a gateway to high math and science" by the end of eighth-grade (Mathews, 2002, ¶ 4). He also found that at the national level only 25% of eighth graders were enrolled in algebra or higher-level classes according to a *Washington Post* survey. However, educational psychologist and education consultant Bracey ridiculed the notion that algebra is the gateway to a good life (Mathews, 2002).

Without dispute, however, there is little opportunity for below-average high school students to include college on their radar screens without algebra, which has often been regarded as the gatekeeper as access to college. Alternative instructional methods for teaching algebra in high school need to be found.

Statement of the Problem

Teachers use student grades and norm-referenced tests to make recommendations on mathematics placements for high school students. Students with a history of inadequate mathematics performance continue to be placed in lower-level mathematics classes that do not prepare them for college or for high paying jobs in the technology sector. If it is true that technology is a tool that supports students' attitudes about learning (Reyes, 1984; Ma & Kishor, 1997) as well as increasing a student's understanding of mathematical concepts (Palmiter, 1991), then what effect does a computer-assisted mathematics program, specifically the Cognitive Tutor Algebra (CTA), have on underachieving students in their study of algebra? The two key null hypotheses for this study are:

H_o^1: The Cognitive Tutor Algebra (CTA) program produces the same change in achievement in developmental-mathematics students as that in average and above average students in a comparison group as measured by the Achievement Levels Test (ALT) for algebra.

H_o^2: The CTA program produces the same change in students' attitudes toward mathematics in developmental-mathematics students as that in average and above average students in a comparison group on test scores as measured by the Fennema-Sherman Mathematics Attitude Scales (FSMAS).

Purpose of the Study and Research Questions

Since the emergence of instructional technology, there has been an emphasis to integrate technology into the classroom to support learning. However, there are few studies on how well technology assists students with constructing their understandings of mathematics principles and concepts. The purpose of this study was to compare and analyze the achievement and attitude results of developmental-mathematics students who used a technology-based algebra program with a representative sample of average and above average students who received instruction in a traditional classroom using an algebra textbook. The researcher addressed the following questions in seeking to answer the null hypotheses for the study. All differences, if found, were tested for significance at $p \leq .05$.

1. What is the difference, if any, between 9th grade treatment conditions with respect to student change on the ALT scores?
2. What is the difference, if any, between 9th grade treatment conditions with respect to race/ethnicity and gender and how do these differences affect ALT scores?
3. What are the simple correlations among selected student-level variables: ALT scores, ALT gain scores, ELL status, and treatment condition?
4. What are the simple correlations among selected classroom-level variables: ALT gain, percentage of ELL

students, percentage of females, and classroom treatment conditions?

5. To what extent do differences between study groups' race/ethnicity, English Language Learner (ELL) status and gender affect ALT scores?
6. What is the difference, if any, between study groups in the amount of change on two of Fennema-Sherman Mathematics Attitudes Scales?

Limitations and Delimitations of the Study

Several delimitations were placed on the study. Some teachers in the district where the study was conducted had concerns regarding the effectiveness of the CTA program and the degree to which the program was adequate and sufficient to teach students to meet the district's standards for Algebra I-II. The majority of 9^{th} graders throughout the district were enrolled in the CTA classrooms, so sampling or choices for participants was restricted to intact groups and to students who were referred to the treatment.

Students selected for the study were not equivalent in the sense that they were selected for placement based on teacher recommendations. Those recommendations were generally based upon student grades and teachers' *perceptions* of student ability. The cut-off score for placement into the treatment (CTA) and comparison groups was generally followed. That is, students who received grades of "As","Bs" and "C+" from teachers of grade 8 mathematics were recommended by teachers and counselors for placement into the traditional, textbook-based, algebra course. Students who received grades of "C" could self select a mathematics course, whether it was the traditional design or the Cognitive Tutor Algebra (CTA). Students who received grades of "C-", "Ds" or "F" were placed in the CTA program. However, this method for selecting students for the treatment (CTA) and comparison group classrooms was not followed precisely. There was "mis-assignment" in terms of the cutoff criteria. Overall, 24% of the cases were misaligned. In addition the researcher had concerns that counselors and teachers who lacked knowledge about the instructional delivery and design of the CTA program may have affected the range of students who would compose each course section.

The researcher had concerns about the equivalence of the level of implementation of the CTA program in each school. The researcher had no involvement in the selection of teachers identified to teach the treatment variable, the extent to which teachers received training on the use of the technological tools, or the quality of the instructors;

therefore; there are major limits regarding generalizations that may be drawn from this study.

Definition of Terms

1. Achievement Levels Tests (ALT) -Content area tests that may be locally-designed by school districts using Rasch-calibrated curriculum, item banks developed by the Northwest Evaluation Association (NWEA).
2. Cognitive Tutor Algebra- (CTA) A computer-based intelligent tutoring system that employs story problems using real-world situations which assists students in acquiring the skills and knowledge aligned to a high school algebra curriculum.
3. Computer Assisted Instruction (CAI)- A method of instruction in which the computer is used to instruct the student and where the computer contains the instruction which is designed to teach, guide and test the student until a desired level of proficiency is attained.
4. Computer-Based Education (CBE)- Used in the broadest of ways, this refers to virtually any kind of computer use in educational settings including drill and practice, tutorials, simulations, instructional management, database development and other applications.

5. English Language Learners (ELL)-Students whose first language is other an English and who have not met language proficiency as determined by local educational agencies (LEAs).
6. Rasch model- Developed by George Rasch, a Danish mathematician. This model is a one-parameter logistic model within item response theory where a person's level on a latent trait and the level of various items on the same latent trait can be estimated independently yet still compared explicitly to one another.
7. RIT Scales -Scales of measurement that use item response theory and the Rasch model. The RIT Scale is a curriculum scale developed by NWEA and uses the individual item difficulty values to estimate student achievement.
8. Traditional algebra course- A course where students primarily use textbooks and other print materials along with instruction from a teacher in a classroom setting.

Organization of the Study

Chapter I has identified the background to the problem, the statement of the problem, the purpose of the study, definitions, limitations and delimitations.

Chapter II reviews the literature related to the role that technology has played in classrooms, particularly in algebra-based situations. The review of literature includes how students' attitudes may be affected when technology is employed in the learning process.

Chapter III details the methodology used in the study including a description of the population, sampling, a discussion of the instrumentation used, the research design, components of the data collected, and the analysis procedures. Chapter IV presents the data in answer to the research questions outlined and a detailed discussion of study group assignment. Chapter V reviews the findings, conclusions, and analyses and presents recommendations for policy and future research.

CHAPTER II

A REVIEW OF THE LITERATURE

The researcher compared and analyzed the achievement and attitude results of developmental mathematics students who used a technology-based algebra program, specifically the Cognitive Tutor Algebra (CTA), with a representative sample of average and above students who received instruction in a traditional classroom setting using an algebra textbook. Rothstein (2002) asserted that there is ongoing interest in the education community around the issue of what resources, applied in what fashion, will produce a given gain in student academic achievement. He claimed that most contemporary education-based literature focuses on one of two resources applications —smaller class sizes or better qualified teachers. This researcher had particular interest in studying the extent to which an intelligent tutoring system, designed around algebra concepts and real-life story problems, can improve student performance with high school freshmen who were identified as developmental mathematics learners.

The review of literature spans 20 years with many studies that focus on the expanding role of technology in today's classrooms as well as related research in the field of cognitive psychology and constructivist learning. The review includes studies of the effects of computer-based algebra systems on student achievement, an overview of Computer-Assisted Instruction (CAI), and constructivist teaching methods in mathematics related to how students learn mathematics. The final section of the review deals with research to date on how students' attitudes are affected when technology is used during the instructional process.

Computers and Cognition

Early applications of Computer-Based Education (CBE) in classrooms from the 1960s were designed to automate forms of tutorial learning commonly referred to as CAI. These systems were designed to teach by providing information of procedural knowledge and then requiring the student to practice in a reinforced environment (Glickman & Dixon, 2002). In the 1970s CBE research focused on experimental studies where learners used CAI to acquire specific skills such as word recognition or math facts (Butzin, 2001).

Since about 1975, some meta-analyses have systematically examined the effects of technology on student outcomes. Niemiec and Walberg (as cited in Waxman, Connett, & Gray, 2002) summarized the findings on 13 quantitative research syntheses conducted between 1975 and 1987 and determined that the average effect size was .42, indicating that the average student who received CAI scored at the 66^{th} percentile of the control-group distribution (i.e., the 50^{th} percentile).

Christmann and Badgett (1997) employed a meta-analytic technique to compare the academic achievement of secondary students during a 12 year period (1984-1995). The researchers selected studies that were correlative, quasi-experimental, or experimental in design and found that CAI had greater effect in the 1980s than it did through 1995. An overall mean effect size of .87 was calculated indicating that on average, students receiving traditional instruction supplemented with CAI attained higher academic achievement than did 57.2% of those receiving only traditional instruction. A -.76 correlation between effect size and years indicated that the effect of CAI on academic achievement declined during the period under review (Christmann & Badgett, 1997).

Waxman, Connell and Gray (2002) synthesized the effects of teaching and learning using technology on student outcomes. The synthesis included quantitative, experimental, and quasi-experimental research and evaluation studies published in journals during a six-year period (1997-2002).

The researcher estimated the effects of teaching and learning with technology on students' cognitive, affective and behavioral outcomes of learning. The researcher calculated 138 effect sizes using statistical data from 20 studies that contained a combined sample of approximately 4,400 students. The mean of the study-weighted effect sizes averaging across all outcomes was .30 ($p \leq .05$), with a 95-percent confidence interval (CI) of .004 - .598.

Waxman et al. (2002) concluded that "this result indicates that teaching and learning with technology has a small, positive, significant ($p \leq .05$) effect on student outcomes when compared to traditional instruction" (p. 10). The mean study-weighted effect size for the 13 comparisons containing cognitive outcomes was .39, and the mean study-weighted effect size for the 60 comparisons that focused on student affective outcomes was .208. The mean study-weighted effect size for the 30 comparisons that contained behavioral outcomes was -.154, indicating that technology had a small, negative effect on students' behavioral outcomes (Waxman, Connell & Gray, 2002).

Kulik (cited in Butzin, 2001) conducted one of the most comprehensive meta-analyses on CAI. He aggregated data from more than 500 individual studies of CBE and concluded that students usually learn more in less time when they receive CAI. It would appear that when used appropriately, CAI could facilitate learning thus creating more time for concept exploration and enrichment. In addition, CAI allows students to take control over their learning.

Kukik's findings were confirmed in a review of 12 meta-analytical studies showing that students who used a form of computer instruction performed between the 56th and 72nd percentiles as compared to students who performed at the 50th percentile in the non-computer classroom (Smith, 2001). Yet, Salerno (cited in Carter & Smith, 2000) contended that it is too early to discern the impact of computer technology on instructional effectiveness.

Baker, Gersten and Lee (2002) synthesized research on the effects of interventions to improve the mathematics achievement of students who were considered low achieving or developmental-mathematics students. Meta-analytic techniques were employed to calculate the mean effect sizes for 15 studies that were published between 1971 to 1999 and that included specific instructional mathematics-based interventions to improve the performance of low-achieving students.

Baker, et al. (2002) reported that in six studies, peer-assisted learning interventions led to positive effects of student performance with an average effect size of .62. However, four of the 15 studies that focused on the use of contextualized approaches (all conducted in the 1990s) stressed real-world applications to mathematical understanding. The overall effect size of these studies was .01, essentially zero. The researchers in two of the four studies found that low achievers seemed not to do well at authentic problem-solving without solid preparation in the underlying mathematical foundations. More research is needed in this area.

Wenglinsky (1998) conducted a national study on the relationship between different uses of educational technology and various educational outcomes. Data were drawn from the 1996 NAEP in mathematics (n = 6227 4^{th} graders and 7146 8^{th} graders). Advanced analytic techniques that modeled and isolated computer effects from other factors involved in student achievement were employed. Results included information on frequency of computer use for mathematics, access to computers at home and in school, professional development of mathematics teachers, and various types of computer uses in schools.

The size of the relationship was measured in terms of estimated grade levels. Wenglinsky (1998) accomplished this by taking NAEP scores between selected characteristics "and dividing by 12.25, the typical difference in mathematics achievement between grade levels" (p.29). The size of the relationship between the positive uses of technology and academic achievement was negligible for fourth graders but substantial for eighth graders.

For example, when technology was used for drill and practice (a low-level use), the relative size of the relationship was -.06 for eighth graders. Students who were engaged in low-level tasks using technology actually lost grade-level growth. Wenglinsky (1998) also found "that Black students were less likely to be exposed to higher-order uses of computers and more likely to be exposed to lower-order uses than White students" (p. 5).

Among fourth graders, students whose teachers used computers mainly for mathematics learning games scored higher than did students whose teachers did not. The research found no association, positive or negative, between fourth graders' scores and either simulation and applications or drill-and-practice (Wenglinsky, 1998). The study suggests that although technology could matter, results are inconclusive on the effects technology has on student achievement.

Hall (2002) conducted a teacher survey on the use of instructional technology in a large, urban school district in Washington (*N* = 938). While the vast majority of teachers responded that they thought that technology is important to the instructional process (62.1%) and that they felt comfortable using technology (71.9%), there seemed to be a disconnect between this comfort level and the use of instructional technology in the classroom. When asked how frequently teachers used technology during the learning process, the majority responded "rarely" to "not at all". Many teachers (68.3%) cited time as the largest obstacle to the integration of technology into the instructional practice.

Intelligent Tutoring Systems

The design of the intelligent cognitive tutor was based on John R. Anderson's advanced computer tutoring theory (ACT) (cited in Anderson, Corbett, Koedinger & Pelletier, 1995). The theory held that a cognitive skill consists in large part of units of goal-related knowledge. The theory employs a production-rule formalism to represent this goal-oriented knowledge (Anderson, et al., 1995).

In 1983 Anderson developed intelligent tutoring systems that tested the ACT theory to see whether students would behave similarly to act like the production-rule model. The researchers developed computer tutors where students practiced programming skills in a program called *Lisp (list processing)* and another that helped students solve problems in a *geometry tutor*. The two tutors embodied key ideas about how CAI might occur (Anderson, et al., 1995).

Schofield, Eurich-Fulcer, and Britt (1994) conducted a two-year qualitative study of microcomputer use in an urban high school in 1985. The researchers explored the impact of an artificially intelligent geometry-proofs tutor on classroom social processes using a treatment and control group design. Intensive classroom observations (n = 183 treatment; n = 93 control) and repeated interviews with students (n = 80 treatment; n = 55 control) were employed. The findings were paradoxical: Students who readily asserted that a teacher provided better assistance than an artificially intelligent tutor in learning how to construct geometry proofs nonetheless preferred to use the tutor to learning in the traditional mode and appeared to demonstrate increased motivation and learning when tutors were used.

Researchers at Carnegie Mellon University partnered with teachers at three high schools in the Pittsburgh School System as part of a National Science Foundation Grant (NSF) to test the effects that the Practical Algebra Tutor (PAT), later redesigned as the Cognitive Tutor Algebra (CTA), would have on non-academic, general-math students. PAT's cognitive model is the result of research on mathematical cognition which showed that students can perform better on algebra word problems under certain conditions than on equivalent algebraic equations (Koedinger & Tabachneck, as cited in Koedinger, Anderson, Hadley & Mark, 1997).

Researchers developed this cognitive tutor based on the concept that math students, particularly students who had not been successful in mathematics in previous classes, will be more successful in solving programs when they are given solid numbers for the starting point and did not know the ending point, instead of starting at an unknown point to reach a known goal (Hubbard, 2000).

Koedinger et al. (1997) conducted the study where students were given post-tests to assess their mathematical performance using the math SAT, the Iowa Algebra Aptitude Test and two problem-based assessments developed by the authors. The researchers used the group as the unit of analysis. There were 470 students in the experimental classes (n=20) who used the Practical Algebra Tutor (PAT) while 155 students in the comparison classes (n=6) used a tradition curriculum. Results showed that the experimental group significantly outperformed the control group on all measures ($p \leq 05$). Koedinger et al. (1997) reported that on average, students in the experimental classes "outperformed students (n = 155) in comparison classes by 15% on standardized tests and 100% on tests that emphasized real world problem-solving and multiple mathematical representations (p. 31). The developers of the CTA program conducted their own evaluation, so there is a need for more research and evaluation in this area.

Constructivist Teaching Methods in Mathematics

According to Fosnot (cited in Telese, 1999), in constructivism knowledge is considered in flux, where the individual internally constructs knowledge or understanding through social and cultural mediation. In essence, the student becomes the maker of meaning thus attaching new knowledge from the constructs of existing knowledge. However, teachers need to attend to the incomplete understanding and the naïve renditions of concepts that learners bring with them to a subject (Bransford, Brown, & Cocking, 2000).

> There is a good deal of evidence that learning is enhanced when teachers pay attention to the knowledge and beliefs that learners bring to a learning task, use this knowledge as a starting point for new instruction, and monitor students' changing conceptions as instructional proceeds (p.207)… For older students, model-based reasoning in mathematics is an effective approach. (p.240)

School algebra has often been defined as techniques for solving equations, producing equivalent algebraic expression, and applying these techniques to word or story problems. Because school algebra for many students is their first encounter with a symbolic language that incorporates the operations of arithmetic, teachers must present this new language within a mathematical expression that helps underachieving students construct this new meaning (Telese, 1999).

The research suggested that lower-ability mathematics students may be able to memorize and apply algebraic algorithms. However, they may not understand the mathematical concepts that underlie the algorithm when they are only given the symbolic representations of algebraic equations. To make the study of algebra available to large, cross sections of a school population, it is instructive to examine the role of constructivism in mathematics education, as many students may need a more concrete or real-world context in which to learn algebra and make the appropriate associations.

Since the emergence of instructional technology, a central question explored in the research is the impact that technology might have on how learning is affected in the mathematics education. Nathan and Resnick (as cited in Heid, 1998) conducted a pretest/posttest control-group design study using ANIMATE, an algebra tutor designed to improve students' success on word problems. The ANIMATE training led to significant performance improvements on standard and novel algebra word problems.

Additional studies have focused on using story problems that help students distinguish between grounded and abstract representations (Koedinger, Alibali & Nathan, 1999). Because story problems are more concrete, or more grounded than abstract, algebraic algorithms, students are better able to make sense of how the abstract language is attached to real objects. Thus, students can understand symbolic representations within the context of the story problem.

As Koedinger, Alibali and Nathan (1999) claimed, students succeed within grounded representations by using informal strategies, and they fail within abstract representations because they fail to understand the foreign language of algebra. Teachers are challenged to find instructional techniques that "bridge" a student's informal or "grounded" knowledge rather than focusing directly on abstract representations that are often found in traditional algebra classrooms. For mathematically challenged students, this "bridge" becomes the essential framework for success or failure.

For example, Keodinger et al. (1997) (as cited in Koedinger, et al., 1999) compared two versions of a computer-based cognitive tutor that contrasted a bridging approach with a textbook's instructional approach to algebraic symbolization. The experimental comparison showed that students learned more from this bridging approach than had students learned from a textbook approach that had them symbolize prior to problem-solving.

Lawson and Chinnappan (2000) studied the relationship between problem-solving performance and the quality of the organization of students' knowledge or knowledge connections. The study involved two groups of college students, one of which was classified as high-achieving

(HA) and the other as low-achieving (LA) students. The HA group was able to access a wider range of problem-relevant knowledge spontaneously than was the LA group [Multivariate F (3, 32) = 3.72, $p < .03$]. This study supports other research in that using a problem-solving context to understand algebraic equations facilitates learning and success in mathematics. Note, however, that this study was conducted with college students.

To study the case for multiple representations when learning the symbolic language of algebra, Brenner et al. (1997) developed a 20-day instructional unit based on four reform-based mathematics principles: (a) multiple representations of concepts, (b) meaningful problem-solving contexts, (c) problem-solving processes, and (d) guided discovery. Study participants (N = 127) came from six intact pre-algebra classrooms at three junior high schools southern California. Prior to the 20-day instructional unit, all students took pretests at their own rate over two class periods. Students received mathematics instruction in algebra, equations, and function based on a multiple representation approach (n = 76) or a traditional approach (n = 51). Following the instruction, all students took corresponding posttests.

The treatment group scored significantly higher than the comparison group on problem representation in the domain of functions: [$F(1,121) = 23.53$, $MSE = .08$, $p \leq .001$]. An analysis of covariance (ANCOVA) was conducted on posttest scores using pretest scores as a covariate and testing for the effects of group (treatment and comparison), teacher, and group-by-teacher interactions. The treatment group scored significantly higher than did the comparison group on problem-solving: [$F(1,121) = 4.19$, $MSE = .57$, $p \leq .05$]. The disaggregated data showed that the language-minority students produced the same pattern of performance as students produced in the overall sample, where treatment group outperformed the control group (Brenner, et al., 1997). This study demonstrates that reformed-based teaching had the same pattern of effect on language-minority students as on the overall school population.

Effects of Computer-based Instruction in Mathematics

The central concept in algebra is function. Thomas (cited in Mayes, 1995) hypothesized that students acquire function in two stages: procedural, where function is viewed as assigning values, and structural, in which the function of an object is itself operated on. Many students have difficulty transitioning to the more abstract structural concepts. Computer tools such as a Computer Algebra System (CAS) have provided a safe and flexible environment for students to make such transitions. Because they are working one-on-one with a computer or in small cooperative learning groups, students receive immediate feedback about their progress from the software tool or from peers who can engage them in conversation around valuable contextual learning.

Fey and Heid (cited in Mayes, 1995) compared high school algebra students in a traditional course to those in a computer-intensive environment. They found that the computer group surpassed the traditional students in the ability to construct mathematics representations of realistic situations, in the use of appropriate combinations of graphical, numerical and symbolic representations.

In a similar experiment, Mayes (1995) compared students, as a unit of analysis, taking a traditional lecture-based college algebra course to students taking an experimental algebra course. Mayes (1995) found that students (n = 61) in the experimental course scored higher than did students (n = 76) in the traditional college algebra. The experimental course stressed active student involvement along with the use of CAS. Experimental-group students scored higher on final measures of inductive reasoning, visualization, and problem solving than did students in the traditional algebra course.

Other tools, such as Computer-Intensive Algebra (CIA) use computer technology to help students develop a rich understanding of fundamental algebraic concepts in real-world settings. Heid (as cited in Heid & Zbiek, 1995) suggested, "CIA students are better able than students in a traditional algebra classes to solve real world (sic) algebra problems, as well as to perform tasks related to specific areas of mathematics modeling" (p.655). Whether students use CAS or CAI, real-world constructs set within the context of authentic problems can help students develop a rich understanding of the algebraic concepts when technology is used as an appropriate teaching tool.

With respect to mathematics assessments and CAS, Hawker, Heid and Judson (cited in Palmiter, 1991) found evidence that students using computer algebra systems in calculus performed as well or better on conceptual exams than did students in traditional versions of the course. Palmiter (1991) investigated whether there were differences between students who have been taught calculus using a CAS to compute limits, derivatives, and integrals and students who used standard paper-and-pencil procedures in knowledge of concepts, calculus procedures and grades in subsequent courses. Students were the unit of analysis. The treatment group (n= 40) used computers over a five-week period, and the traditional students (n= 41) took calculus over 10 weeks without the use of computers. The treatment group significantly outscored the traditional group on both the conceptual and computational exams ($p \leq .001$).

Goetzfried and Hannafin (1985) examined the effects of externally versus internally controlled CAI strategies on the accuracy and efficiency of mathematics rule and application learning of low-achieving seventh-grade students (n = 47). Students were selected based on poor performance on standardized achievement tests. The CAI design included: adaptive control (externally controlled), learner control with advisement (internally controlled) and linear control (no advisement, no control to select additional examples and no externally imposed program decision; students could only control the pace of the lessons). Students were randomly assigned to one of the three treatment groups. They were categorized as "below average" if standardized test scores were above the 20th percentile and "low" if standardized test scores were below the 20th percentile.

A significant difference was found in instructional time for CAI strategy, [$F(2,38) = 15.80$, $p \leq .001$]. The linear strategy averaged less time to complete than both the externally controlled adaptive strategy, ($p \leq .05$), and the learner advisement strategy, ($p \leq .01$). A significant effect was detected for prior achievement [$F(1.38) = 4.88$, $p \leq .05$]. Below average students used less time to complete treatments than did low achieving students. "The adaptive and advisement CAI control strategies used in this study required greater instructional time with no associated gain in achievement" (Goetzfried & Hannafin, 1985, p. 277).

Technology has been used with students who have a limited or a developmental knowledge of mathematics in order to enrich their mathematical understanding. In a teaching experiment, Schultz and Noguera (2000) used CAS to teach a low-level university mathematics course as part of a teaching experiment. While no formal statistical comparisons with other versions of the course occurred, the researchers found that students were successful in using different types of functions to solve a variety of problems drawn from real-world situations. Student emphasis was on thinking about mathematics and less on computation. The focus was on setting up and solving equations to model situations instead of plugging numbers into a given formula and practicing algorithms. The evaluation instrument was a survey designed by the instructors (researchers). The authors of the paper were the instructor and the assistant and may have introduced a bias toward the use of technology.

In addition to software tools such as CAS, technology tools include programs such as Learning Logic, an integrated-learning system that covers the high school Algebra I curriculum. Carter and Smith (2000) determined if use of Learning Logic had an effect on student performance in Algebra II. Four high schools were selected for the study. In all four schools, Algebra I classes were taught with the use of Learning Logic and some Algebra I classes were taught using traditional methods. The researchers found "no significant interaction between school and method of instruction ($F(3,216) = 1.17$, $p \geq .05$)" (Carter & Smith, 2000, p. 4).

In summary, there is conflicting evidence on the degree to which computer tools can provide authentic, context-rich environments to teach students algebra. Some research suggests developmental mathematics students may need context-rich, inter-active classrooms in order to help them construct their understandings of the symbolic language of algebra.

Attitudes and Mathematics Achievement

Studies document the relationship between mathematics achievement and attitudes, including that such relationship is causal. Ma (1997) reported that meta-analyses have confirmed that a more positive attitude toward mathematics (ATM) contributes to a higher level of achievement in mathematics (AIM). It seems plausible that positive attitudes can yield positive mathematics achievement. In a study that used technology, Pierce and Stacey (2001) suggested that students' attitudes toward the use of CAS for learning mathematics were positive; however, their study did not conclude that there was a demonstrable change in student achievement resulting from use of computer tools to teach algebra.

Although researchers have published studies on the causal relationship between ATM and AIM, Ma (1997) suggested that few studies have investigated the reciprocal relationship between ATM and AIM. Using data from a Dominican national evaluation of high school mathematics (*N* = 1,044), the researcher found that a reciprocal or interactive nature between attitudes toward mathematics (ATM) and achievement in mathematics (AIM) can substantially modify their causal relationship. One revealing finding in this study was that "it is the feeling of enjoyment, not the feeling of difficulty, that directly affects mathematics achievement" (Ma, 1997, p. 228.)

There has been considerable research around the definition of ATM. Reyes (1984) used ATM as a general concept that included beliefs about self and about mathematics. While Reyes (1984) reported that there were positive correlations between attitude and mathematics, the strength of that relationship is not clear. Because of the lack of consensus in the literature concerning the relationship between mathematics and achievement, Ma and Kishor (1997) performed a meta-analysis to integrate and summarize the finding from 113 primary studies.

Results of these studies were transformed into a common effect size (ES) measure on a number of variables: grade, ethnic background, sample selection, sample size and date of publication. They reported correlations between zero and above .40. Their research suggested a trend exists which indicated stronger ES between grades 7-9 than grades 1-4. This has implications for student attitudes in high school. As students experience more success with mathematics, achievement may increase as well.

Summary

A review of the literature and research around attitude may provide an impetus for redesigning algebra classes for students whose standardized achievement data indicate that they may require a contextual teaching approach. Some research supports the causal relationship between student attitudes and academic achievement. One challenge for mathematics educators centers around the design of engaging lessons and the enactment of constructivist learning strategies that may enable students to move beyond the memorization of abstract algorithms and toward a contextual, reality-based understanding of how algebraic functions are used in everyday problems. Algebraic competence is essential in today's world. For example, distribution and communication networks, laws of physics, population models and statistical results are all represented in the symbolic language of algebra (NTCM, 2000), so students must be prepared to use their mathematical knowledge to help them understand their ever-changing world.

The review of research and literature in Chapter II highlights a number of studies around the use of technology and its impact to the learning process. The field of cognitive psychology and its relation to developmental mathematics students was reviewed. Chapter III describes the research design, components of data collection and data analysis procedures used in this study.

Chapter III

METHODOLOGY

This chapter details the methodology used in the study. The first section deals with a description of the population studied followed by a discussion of instrumentation used to collect student data. The chapter outlines of the research design, the various components of data collection, a discussion of treatment and comparison group methodologies and the analysis procedures. The purpose of this study was to compare and analyze the achievement and attitude results of developmental-mathematics students who used a technology-based algebra program, the Cognitive Tutor Algebra (CTA) with a representative sample of average and above average students who received instruction in a traditional setting using an algebra textbook. Six research questions guided the inquiry on the differences between the treatment and comparison groups on Achievement Levels Test (ALT) scores.

Population

The study was conducted in the state of Washington, in a large, urban system. Student enrollment consisted of nearly 27,000 (2003) students in 4 large, comprehensive high schools (10-12), 7 junior high schools (7-9), 28 elementary schools (K-6) and one K-12 alternative setting. Minority students accounted for 33% of the total student population; 11% were classified as English-language Learners (ELL) and 32% as free and reduced lunches. Approximately 15% of students were served in special education. Highly capable elementary students represented nearly 4% of the total elementary school population.

Study participants (*N* = 1027) included all ninth graders at the seven junior high schools and ninth-grade students who had attended the district's K-12 school. The demographics of the population in this study are outlined in Table 1.

Each school's ninth grade population was similar in demographics to the population of the entire school. One school had a non-White majority. The number of ELL students varied from school-to-school, and three schools had ELL populations in excess of 10%. The 7-9 schools had similar sizes of ninth-grade populations except for the K-12 alternative school which had only one ninth-grade classroom.

Table 1

Demographics of Student Population of Schools and in Grade 9 of the Study

School/ Grades	Size (n)		White %		Black %		Asian %		Other %		FRL %		ELL %		Sp.Ed. %	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1 (7-9)	1044	199	86	86	4	10	4	1	6	4	19	18	1	0	20	18
2 (7-9)	816	182	43	42	22	28	16	18	19	13	59	58	13	14	16	14
3 (7-9)	974	182	81	81	7	5	8	6	4	6	21	24	7	8	14	13
4 (7-9)	884	197	65	64	9	12	20	18	6	6	29	23	11	2	10	13
5 (7-9)	1032	195	65	58	10	14	20	19	5	8	23	33	2	14	13	9
6 (7-9)	860	179	73	69	6	8	15	16	6	7	18	21	9	10	8	7
7 (7-9)	946	173	58	60	18	19	15	10	9	10	44	42	12	11	11	11
8 (K-12)	104	25	78	72	10	4	5	12	7	12	19	20	0	0	24	28

Note. A= School; B= Grade 9; FRL= Free/Reduced Lunch Status; Percentages may not equal 100% due to rounding.

Participants included all ninth-grade students (N = 1027) enrolled in mathematics classrooms district-wide where complete data were collected to measure outcomes in achievement and attitudes. Complete data included pre and posttest data on ALT and Fennema-Sherman Mathematics Attitudes Scales (FSMAS), previous math grade, treatment and classroom assignment code. Students in the CTA (treatment) classrooms were designated 1, and students in the comparison classrooms were designated 0. The eight schools were listed alphabetically and within each school, teachers were listed alphabetically. Consequently, classroom assignment codes were allocated to teachers in the order in which their name appeared on the classroom teacher roster from 1- 69.

To measure student attitudes about mathematics, a sampling of the comparison and CTA populations was employed. One comparison and one CTA classroom from each school was randomly selected to participate in the pre and posttest FSMAS, yielding 319 students from randomly selected intact classrooms. Of that group, 157 students agreed to participate in the FSMAS sample from both comparison and CTA classrooms. From those 157 students, 153 students had both pre and posttest FSMAS data.

The comparison group consisted of students from 36 traditional or textbook-based algebra classrooms, and the CTA group consisted of students from 33 classrooms using the CTA program. These classrooms were distributed across 8 schools as shown in Table 2.

Table 2

Distribution of CTA and Comparison Classrooms by Schools

School ID	Classroom Condition	
	CTA Rooms	Comp. Rooms
1	4	6
2	4	4
3	5	7
4	6	4
5	5	7
6	3	3
7	5	5
8	1	0
Study Group Totals	33	36

The data were collected during the 2002-2003 school year. Students whose individual education plans (IEPs) did not allow them to participate in general education mathematics and students who were enrolled in higher-level mathematics classes were excluded. All ninth-grade algebra teachers participated in the study (n = 25).

Instrumentation and Validity

As part of an annual testing program, every eighth-grade student was assessed in 2002 and 2003 using the Achievement Levels Test (ALT) developed by the Northwest Evaluation Association (NWEA). NWEA scores are commonly reported on the RIT scale that provides assessment information to classroom teachers and parents. The RIT Scale is short for Rasch Unit, honoring George Rasch, the Danish mathematician who developed the underlying theory for this type of measurement (Northwest Evaluation Association, 2003). The RIT Scale is a curriculum scale that uses individual item difficulty values to estimate student achievement. The RIT Scale relates numbers on the scale directly to the difficulty of items on the tests, and the scale is designed as *equal interval.* Equal interval means that the difference between scores is the same without regard to a student being at the top, bottom or middle of the RIT Scale, and the scale has the same meaning regardless of grade level. This concept is known as item response theory (NWEA, 2003).

Item response theory and the Rasch model were used to create a scale that allows the sensitive measurement of students' growth on an achievement continuum. Ingebo (1997) contended that this underlying scale or continuum is a constant, against which one can judge achievement and achievement growth. Over 1,050,000 students were included in the August 2002 norms, many of whom took more than one test in more than one testing season; as a result, the total number of tests used to develop the status norms in 2002 is 3,041,711 (NWEA, 2002).

The FSMAS have been used extensively in research on gender differences in mathematics learning outcomes and in studies of attitudes toward mathematics (Melancon, Thompson & Becnel 1994; Forgasz, Leder & Gardner, 1999). The complete FSMAS instrument has nine scales measuring constructs "hypothesized to be related to the learning of mathematics by all students and/or cognitive performance of females" (Fennema & Sherman, 1976, p. 1). Each scale contains 12 statements about mathematics—6 positively worded statements and 6 negatively worded statements. Respondents agree or disagree using a Likert Scale.

Walberg and Haertel (as cited in Forgasz, Leder & Gardner, 1999) claimed that the original 1976 study is one of the most cited articles in mainstream journals of educational psychology even though there are societal changes where achievement differences between males and females appear to be declining or in some cases reversed. In the 1970s there was a gender gap where male students outperformed female students in mathematics. Recent research indicates that several items in the "mathematics as a male domain" scale of the FSMAS may no longer be valid.

When the original scale was developed in the 1970s, prevailing views suggested that mathematics was a male domain. In international research, Forgasz, Leder and Gardner (1999) summarized four studies that challenged aspects on the FSMAS-the Mathematics as a Male Domain (MD) scale, one of the nine original scales. Forgasz et al. (1999) revisited the assumption that the scale is valid by examining data from the four international studies.

In two of the four studies, students indicated whom they considered best at mathematics along with reasons. In the remaining two studies, researchers used questionnaires similar to the FSMAS on gender-role orientation and the measurement of respondents' attitudes. Some respondents viewed females as both better at mathematics and more prepared to work harder than were males, thus challenging an inference that might be drawn from a negatively worded statement. Using factor analysis, one of the four studies suggested that the groups of positively and negatively worded statements on the MD may be measuring different effects over time.

In another study, Melancon, Thompson and Becnel (1994) explored the measurement integrity of the FSMAS by employing data provided by public elementary school teachers of mathematics. The purpose was to determine if the scores on the FSMAS correlated with scores on a measure of preferences to give socially desirable responses on attitude measures. Factor analysis was the major analytic tool to evaluate score validity. Melancon et al. contended, "that factor analysis is seminal to the evaluation of the validity of data in hand, as well as to construct elaboration" (p. 188). With the coefficients near zero, results reasonably supported a conclusion that FSMAS scores were valid.

Research Design/Samples

The design for this study was not strictly experimental, as samples (as described below) were not randomly selected from an entire population. The design can, however, be referred to as quasi-experimental, following Campbell and Stanley (1963). This design, called by Campbell and Stanley the Nonequivalent Control Group Design, can show both high internal and high external validity. This means that with care, results may be generalized to the population.

For this study, the treatment group included all students enrolled in the CTA classes at all seven junior high schools and in the ninth-grade classroom at the alternative school. Students were selected for treatment based on teacher recommendations that were largely determined by students' grades from their eighth-grade mathematics class as well as their scores on the eighth-grade ALT. The researcher intended that students in the treatment group would be those whose "math profile" targeted them by counselors and teachers as low-performing. As eighth-graders, these students who received year-end mathematics grades of "C-", "D" or "F", were randomly assigned at each building to a mathematics teacher.

The researcher also intended that the comparison group participants were students who received grades of "As", "Bs" or "C+" in eighth-grade mathematics and whose teachers recommended them for traditional algebra instruction. Students who received grades of "C" were able to select either group. Students selected for the comparison group were to be largely average and above average students. Highly capable mathematics students were identified as accelerated math students in seventh grade; consequently, they took algebra as seventh or eighth graders and were not part of the present study.

Effects of the CTA program on achievement and attitude were examined through a regression-discontinuity design with multilevel modeling of the dependent variables, pre and post-test scores on the ALT, and pre and post-test scores from two of the original nine scales from the FSMAS. A multilevel model is necessary to separate the effects of individual student differences, classroom composition and the mathematics program on the dependent variables (Bryk & Raudenbush, 2002).

A regression-discontinuity design is called for when individuals are assigned to a program or comparison group based on whether they fall above or below the cut-off score on a pre-program measure (Trochim, 1984). Because the assignment of students to CTA (treatment) or comparison classrooms was to be made on the basis of prior math grade, where students with grades above "C" would be in comparison classrooms and students below "C" would be in CTA classrooms, and "C" students were free to self-select, a regression-discontinuity design is appropriate. The pre and posttest ALT scores served as the dependent variables for achievement with independent variables consisting of ELL status, gender and race/ethnicity. In measuring differences in student attitudes, the pre and posttest FSMAS scores served as the dependent variables.

Treatment

The treatment focused on the use of the CTA program and its impact on student achievement and on student attitudes toward mathematics. The curriculum and related software tools employed a problem-solving methodology by which students would use the intelligent computerized tutors to learn the symbolic language of algebra and its application to real-world situations. The intent was for each student to work one-on-one in a safe, computer environment. The CTA group was assigned in a computer lab for 40% of the instructional time with the remaining 60% of the instructional time being spent in a classroom.

The scope and sequence of the curricula taught in the CTA classrooms strongly resembled the scope and sequence of the traditional algebra course (See Appendix D). The degree of coverage on specific topics was not monitored and may have varied. Comparison-group instruction employed typical classroom strategies that included teacher lecture and presentation using large and small-group instruction. The major teaching tool was use of a comprehensive algebra textbook. In both the comparison and CTA settings, class sizes were similar, roughly 23 students per classroom.

All teachers had teaching credentials and were endorsed to teach high school mathematics. All CTA instructors participated in a four-day, intensive training on the use of the computer-based software. Topics ranging from cooperative learning strategies to constructivist learning environments were also included in the training. Instructors for the comparison group spent three days familiarizing themselves with the content of an algebra textbook that was different from the text used in the treatment classrooms.

Data Analysis Methods

Recognizing that classrooms differ in student composition (e.g., distribution of student demographics, socio-economics of families, etc.) implies recognizing the hierarchical nature of the data. If CTA classrooms differed from comparison classrooms in composition, a substantial but unmeasured effect of composition on achievement gain could either mask a real treatment effect or make a negligible effect look falsely significant. Bobbett, French and Achilles (1993) found that the statistical analysis selected to examine the impact of predictor variables on the dependent variable can have a large impact on the findings of a study.

Bryk and Raudenbush (1992) contended that hierarchical data structures often occur in educational measurement where students are nested within classrooms, grade structures and schools. Researchers need analytic methods that can accommodate the hierarchical nature of such data. Bryk and Raudenbush (1992) posited that:

> The research problem has thee foci: the individual growth of students over the course of the academic year, …the effects of personal characteristics and

> individual educational experiences on student learning, and how these relations are in turn influenced by classroom organization and the specific behavior and characteristics of the teacher. Correspondingly, the data have a three-level hierarchical structure. The Level-1 units are the repeated observations over time, which are nested within the Level-2 units of persons, who in turn are nested within the Level-3 units of classrooms or schools. (p.2)

Hierarchical Linear Modeling (HLM) provides what Bryk and Raudenbush (1992) referred to as an integrated approach for studying the structure and predictors of individual growth. HLM is a random coefficient modeling technique that can be used to analyze data collected within educational groups (Nezlek & Zyzniewski, 1998). HLM was used for this research because random factors are identified at more than one level of the data hierarchy. HLM, a form of general linear regression, accounts for multilevel or "clustered" data.

Because the study used a nonequivalent comparison group and cutoff scores were intended to determine student assignment, a regression-discontinuity (RD) design was the appropriate statistical model. According to Valasquez

(2003) the RD design was first used in the mid-1970s in the nationwide evaluation system for compensatory education programs funded under Title I. Recently it has been used in medical trials and in social program interventions.

In RD designs, participants are assigned either to the treatment or comparison groups on the basis of a cut-off score on a specific pretest measure. The researcher found that 24% (n = 249) of the total number of cases (N = 1027) were mis-assigned. As a result, an RD design with an adjustment for fuzzy assignment was used. Trochim (1984) offered two methods for estimating relative assignment. The procedure used in this study was *the nearest neighbor moving average method* where the following steps were involved (Trochim, 1984):

(1) The set of observations (x_i, y_i, and z_i) are put in ascending order according to the pretest, x_i.

(2) Values of A and B are computed as the greatest integer part of

a. $A = n^{7/10}/2$

b. $B = n^{4/5}/2$

c. where n is the number of cases

(3) The relative assignment variable, z_i (i.e., $E(z_i|x_i)$), and y_i (i.e., $E(y_i|x_i)$) and y_i (i.e, $E(y,_i^2)$)are estimated

Quantitative Data Collection

The quantitative design of this study included five data collection components as shown in Table 3.

Table 3

Data Collection Components, Comparative Mathematics Study, 2002-2003

Data Points	Type of Data	Collection Time
1	8th Grade Math Grade	June, 2002
2	8th Grade ALT Scores	May, 2002
3	FSMAS Pretest	April 2003
4	9th Grade ALT Scores	May 2003
5	FSMAS Posttest	June 2003

The first data collection included the students' second-semester grade-point equivalency from their eighth-grade class. The second data collection included the students' RIT from the eighth-grade mathematics portion of the ALT, (5/2002) as part of the district's annual assessment program. This served as the pre-test measure.

In April, 2003, two scales of FSMAS were used with a random sample of 157 students who were in intact groups and comprised the third data collection. This measure served as a retrospective pre-test; students were asked to recall from their eighth-grade experiences how they felt about mathematics at the end of their eighth-grade year. The 157 students came from two randomly selected classes—one from the CTA group and one from the comparison group.

The fourth data collection (5/2003) occurred when students took the ninth-grade ALT as part of the district's annual assessment program. This test served as a basis for comparing the levels of achievement for both groups. The fifth data collection (6/2003) included the same two FSMAS scales and served as a post-test for those same students who were pre-tested in April 2003. The post-test measured students' attitudes toward mathematics after their ninth-grade algebra course.

Summary

Chapter III has presented the methodology and research design for this study. The researcher outlined why the RD design was appropriate for this study. He described the nature of the treatment condition and the comparison group. In addition, data analysis methods were delineated along with a discussion of the five data collection components. Chapter IV provides the data and results of analyses. Tables are included as appropriate.

CHAPTER IV

PRESENTATION AND ANALYSIS OF THE DATA

The purpose for the study was to compare achievement and attitude results of developmental mathematics students who used a technology-based algebra program with results from a representative sample of average and above average students who received instruction in a traditional classroom setting using an algebra textbook. The achievement null hypothesis states that the Cognitive Tutor Algebra (CTA) program produces the same change in achievement in developmental mathematics students as that in average and above average students in a comparison group as measured by the Achievement Levels Test (ALT) for algebra. The null hypothesis for attitude states that the CTA program produces the same change in students' attitudes toward mathematics in developmental mathematics students as that in average and above average students in a comparison group as measured by two Fennema-Sherman Mathematics Attitude Scales (FSMAS).

Chapter IV presents the data and analyses to answer research questions outlined below that have guided this inquiry. The study focused on six questions:

1. What is the difference, if any, between 9^{th} grade treatment conditions with respect to student change on the ALT scores?
2. What is the difference, if any, between 9^{th} grade treatment conditions with respect to race/ethnicity and gender?
3. What are the simple correlations among selected student-level variables: ALT score, ALT gain scores, ELL status, and treatment condition?
4. What are the simple correlations among selected classroom-level variables: ALT gain, percentage of ELL students, percentage of females, classroom treatment conditions?
5. To what extent do differences between 9^{th} grade treatment conditions in race/ethnicity, English Language Learner (ELL) status and gender affect ALT scores?
6. What is the difference, if any, between treatment conditions in the amount of change on two FSMAS?

Data Presentation for Treatment Condition Assignment

This study employed a quasi-experimental design with nonequivalent control groups. As outlined in Chapter III, the regression-discontinuity design (RD) was used because students were to be assigned based on a "cut-off" score. Students with previous math grades below "C "were intended to be in CTA or treatment classrooms, students above "C" were intended to be enrolled in comparison or traditional algebra classrooms, and students with "C" grades were free to choose either classroom. The information in Table 4 shows the range of grade 8 math grades, numerical equivalencies (GPA) and student assignment into study groups. For each grade, the actual number of students assigned to CTA and comparison classrooms as compared to the intended assignment is depicted.

Fewer students were assigned into comparison classrooms (n = 468) as compared to expected assignment in those classrooms (n = 588). More students were assigned to CTA classrooms (n = 559) as compared to expected assignment in those classrooms.

The 249 students mis-assigned relative to the original "cut-off" score for classroom assignment represented 24% of the total cases of student assignment. Judd and Kenny (as cited in Trochim, 1984) contended that if fewer than 5% of the cases are mis-assigned, the sharp regression-discontinuity (RD) analysis will not be seriously biased.

Table 4

Classroom Assignment to the 9th Grade Study Groups by Prior Math Grade, Comparative Mathematics Study, 2002-2003

Math Grade[a]	GPA	Comparison Classrooms Actual (*n*)	Comparison Classrooms Expected (*n*)	CTA Classrooms Actual (*n*)	CTA Classrooms Expected (*n*)
A	4.0	93	124	31	0
A-	3.7	56	72	16	0
B+	3.3	39	54	15	0
B	3.0	76	129	53	0
B-	2.7	46	80	34	0
C+	2.3	28	50	22	0
Subtotal		338	509	171	0
C	2.0	52	78.5	105	78.5
C-	1.7	27	0	50	77
D+	1.3	11	0	48	59
D	1.0	22	0	117	139
F	0.0	18	0	68	86
Subtotal		78	0	283	361
Total		468	588	559	439

Note. [a]Math Grade is the student's math grade from 8th grade

Chi Square was used to test for significance of departure from the strict assignment. The formula for the Chi Square test for association statistic is the following:

$$X^2 = \Sigma \frac{(\text{Observed Count} - \text{Expected Count})^2}{\text{Expected Count}}$$

Chi Square results indicate a significant departure ($p \leq .001$) from the strict assignment of students into CTA and comparison classrooms (Table 5).

Examination of the standardized residuals show significant departures from the expected assignment into study groups in 20 of the 22 cells where the standardized residuals are 2 or greater. Student mis-assignment spans the entire range of grades of A through F in both CTA and comparison conditions. A standardized residual of -4.9 was observed for the number of students who should have been assigned into the comparison classrooms. The expected count of students who should have been assigned into comparison classrooms was 588 and only 468 were actually assigned. Thus, proportionately fewer students were assigned to the comparison classrooms. A standardized residual of 5.7 was observed for the number of students who should have been assigned into the CTA classrooms. The expected count of students who should have been assigned into comparison classrooms was 439 and 559 were actually assigned. Thus, proportionately greater numbers of students were assigned to the CTA classrooms.

Table 5

Expected vs. Observed Assignments to CTA and Comparison (Comp.) Groups, 2002-2003

Grade	GPA		Comp.	CTA	Total
F	0.0	Observed Count	18	68	86
		Expected	0	86	86
		Std. Residual	18	-1.9	
D	1.0	Observed Count	22	117	139
		Expected	0	139	139
		Std. Residual	22	-1.9	
D+	1.3	Observed Count	11	48	59
		Expected	0	59	59
		Std. Residual	11	-1.4	
C-	1.7	Observed Count	27	50	77
		Expected	0	77	77
		Std. Residual	27	-3.0	
C	2.0	Observed Count	52	105	157
		Expected	78.5	78.5	157
		Std. Residual	-3.0	3.0	
C+	2.3	Observed Count	28	22	50
		Expected	50	0	50
		Std. Residual	-3.1	22	
B-	2.7	Observed Count	46	34	80
		Expected	80	0	80
		Std. Residual	-3.9	34	
B	3.0	Observed Count	76	53	129
		Expected	129	0	129
		Std. Residual	-4.7	53	
B+	3.3	Observed Count	39	15	54
		Expected	54	0	54
		Std. Residual	-2.0	15	
A-	3.7	Observed Count	56	16	72
		Expected	72	0	72
		Std. Residual	-1.9	16	

Grade	GPA		Comp.	CTA	Total
A	4.0	Observed Count	93	31	124
		Expected	124	0	124
		Std. Residual	-2.8	31	
Total		Observed Count	468	559	1027
		Expected	588	439	1027
		Std. Residual	-4.9	5.7	

Trochim (1984), after Campbell and Stanley (1963), called this type of mis-assignment *fuzzy* assignment. When assignment is not strict in RD and nonequivalent group designs, an analytic adjustment is needed. Spiegelman (as cited in Trochim, 1984) devised the *nearest neighbor moving average* adjustment, which was employed in this study.

Trochim (1984) posited that the moving average estimates of relative assignment appear to yield unbiased estimates of gain for most models and conditions that he studied. Using the Create function in SPSS, a combination of prior math grade and assignment (1 to CTA group and 0 to comparison group) was used to derive the relative assignment or moving averages. Table 6 highlights the means and standard deviations of the relative assignments for both the CTA and comparison groups. The mean of the estimated assignment for the comparison group is .44, which is closer to the assignment of 0 than 1; this relative assignment has a standard deviation of .20. The mean of the estimated assignment for the CTA group is .63 with a standard deviation of .21; this relative assignment is closer to the actual assignment code of 1 than 0.

Table 6

Mean and Standard Deviation (SD) of Relative Assignment of Study Groups

Condition	N	Min.	Max.	Mean	SD
Comparison	468	.16	.88	.44	.20
CTA (Treatment)	559	.16	.88	.63	.21
Population	1027	.16	.88	.54	.23

These moving average values were substituted in the equations for the values of 0 (comparison) and 1 (CTA or treatment) to model achievement gain in the HLM models.

Quantitative Results for Achievement

The original data set for achievement consisted of 1332 student records that could have included pre and posttest scores on the ALT, previous math grade, treatment code, classroom assignment number. However, 305 students had missing data (e.g., no pretest measure or no prior math grade, etc.), and those students were eliminated from the study. This resulted in 1027 student records for the final ALT analysis. The population of 1027 students closely resembled the original set of 1332 as shown in Table 7.

Table 7

Comparison of Populations by Gender, ELL Status, and Study Group Assignment

	N	Gender %		ELL %		Study Group Assignment %	
		M	F	Y	N	CTA	Comp.
Original Data Set	1332	52	48	8	92	57	43
Population Used	1027	51	49	7	93	55	45
Excluded	305	56	44	13	87	65	35

A subset of 157 students also had pre and posttest responses to the FSMAS. The quantitative results for the attitudes portion of the study are discussed in greater detail later in this chapter.

The researcher sought to determine whether or not student participation in the CTA program (the treatment group) produced ALT achievement gains that were significantly greater or larger than gains realized for the comparison group.

The largest ALT gain from spring 2002 to spring 2003 was observed with the CTA students. CTA students' ALT mathematics mean increased from 228.7 in 2002 to 241.4 in 2003—a gain of 12.7 RIT units; the comparison group mean increased from 242.5 in 2002 to 251.9 in 2003 -- a gain of 9.4 RIT units (see Table 8).

Table 8

CTA Group and Comparison Group Change on ALT Means, Comparative Mathematics Study, 2002-2003

Group	Year	N	Min.	Max.	Mean	SD	Mean Gain
CTA	2002	559	150	258	228.7	15.04	12.7
	2003	559	226	265	241.4	6.53	
Comp.	2002	468	209	260	242.5	9.10	9.4
	2003	468	222	270	251.9	7.23	

In a preliminary analysis, the researcher used a dependent matched-pair sample *t* test to compare mean gains on the 2002 and 2003 ALT (see Appendix A). The two mean gains were significantly different at .000. However, the *t*-statistic tested the significance of a biased estimate of the CTA treatment effect. The bias stemmed from failure to consider how students were actually assigned and the hierarchical nature of the data. Thus, the researcher used Hierarchical Linear Modeling (HLM) to address whether or not the CTA program was predictive of ALT gain scores.

The researcher also sought to determine whether the results of the ALT were different for different groups with respect to race/ethnicity, ELL status and gender. Table 9 displays ALT achievement results disaggregated by ethnic group and treatment condition.

Table 9

ALT Achievement Results Disaggregated by Comparison and CTA (Treatment) and Ethnicity, 2002-2003

Ethnicity	Group/Year	N	Min.	Max.	Mean	SD	Mean Gain
Asian	Comparison						10.8
	2003 ALT	64	235	268	254.1	7.24	
	2002 ALT	64	211	257	243.3	9.03	
	CTA						16.08
	2003 ALT	63	226	255	243.1	6.05	
	2002 ALT	63	159	250	227.0	17.35	
African-American	Comparison						14.76
	2003 ALT	33	236	268	250.1	7.56	
	2002 ALT	33	209	257	235.3	13.08	
	CTA						14.93
	2003 ALT	93	229	255	240.6	6.04	
	2002 ALT	93	183	256	225.7	15.53	
Hispanic	Comparison						11.91
	2003 ALT	21	236	265	249.7	7.32	
	2002 ALT	21	211	252	237.8	11.23	
	CTA						14.74
	2003 ALT	38	229	263	239.8	6.65	
	2002 ALT	38	192	251	225.0	14.20	
Native American-Indian	Comparison						10.25
	2003 ALT	4	241	258	249.8	8.06	
	2002 ALT	4	222	251	239.5	13.77	
	CTA						7.00
	2003 ALT	5	231	246	237.4	5.60	
	2002 ALT	5	213	253	230.4	17.05	
White	Comparison						8.49
	2003 ALT	346	222	270	251.8	7.12	
	2002 ALT	346	210	260	243.3	8.06	
	CTA						11.34
	2003 ALT	360	226	265	241.5	6.67	
	2002 ALT	360	150	258	230.2	14.39	

The Gain column in Table 9 shows that Asian students in the CTA group had the greatest gain in mean scores on the pre and posttest ALT with a gain score of 16.08 (n = 63) as compared to the group Native American-Indian students in the CTA group who had the least gain of 7 (n = 4). Table 10 displays the ALT achievement results disaggregated by gender.

Table 10

ALT Achievement Results Disaggregated by Treatment Condition and Gender, 2002-2003

Gender	Group/Yr.	N	Min.	Max.	Mean	SD	Mean Gain
Male	Comparison						
	2002 ALT	200	210	260	243.19	8.20	7.66
	2003 ALT	200	222	268	250.85	7.44	
	CTA						
	2002 ALT	317	159	258	229.01	14.08	11.84
	2003 ALT	317	226	265	240.85	7.06	
Female	Comparison						
	2002 ALT	268	209	260	241.91	15.99	10.74
	2003 ALT	268	235	270	252.65	6.99	
	CTA						
	2002 ALT	242	150	258	228.33	16.23	13.75
	2003 ALT	242	229	265	242.08	5.71	

Table 10 shows that females in the CTA program (n = 242) had greater gain in mean scores when compared to females in comparison classrooms (n = 268) or males in both study groups (n = 517). Females in the CTA program gained 13.75 RIT units as compared with the males in the CTA program (n = 317) whose gain score was 11.84.

Additionally, males in the CTA program (n = 317) had a gain score of 11.84 in contrast to males in the comparison classrooms (n = 200) whose ALT gain was 7.66. A paired samples t-test (See Appendix C) confirmed each of the paired differences was significant at ($p < .000$). However, gender per se may not be producing the significant difference due to how students were assigned to CTA classrooms and the hierarchical nature of the data. Table 11 shows the results of ALT achievement gains by ELL and non-ELL status.

Table 11

ALT Achievement Results by ELL and Non-ELL Status

Status	Group/Yr.	N	Min.	Max.	Mean	SD	Mean Gain
Non-ELL	Comparison						
	2002 ALT	455	209	260	242.70	8.73	9.2
	2003 ALT	455	222	270	251.88	7.17	
	CTA						10.43
	2002 ALT	501	193	258	231.18	12.22	
	2003 ALT	501	226	265	241.61	6.5	
ELL	Comparison						
	2002 ALT	13	210	259	234.08	15.99	17.61
	2003 ALT	13	238	266	251.69	9.41	
	CTA						31.97
	2002 ALT	58	150	245	207.43	19.73	
	2003 ALT	58	226	255	239.40	6.58	

The gain column in Table 11 illustrates that ELL students had the greater gain in mean scores using the pre and posttest ALT gain scores. Non-ELL students in the CTA group (n = 455) gained 9.2 RIT units as compared to non-ELL students (n = 501) in comparison classrooms who gained 10.43 RIT units. The greatest ALT gains, however, were found with ELL students. ELL students in comparison classrooms (n = 13) gained 17.61 RIT units as compared with ELL students in CTA classrooms where the gain was measured at 31.97 RIT units. There were over four times as many ELL students in treatment (CTA) classrooms (n = 58) as were assigned to comparison classrooms (n = 13).

The researcher was also interested in the strength of relationships between selected student-level independent variables (e.g., 2003 ALT and ELL status, etc). The Pearson Product Moment Correlation statistic was used to estimate the strength of these relationships. Table 12 displays the data. Several relationships are worth noting. The correlation between the student-level 2003 ALT score and treatment condition was -.606 (r = .-61) $p \leq .001$. This negative relationship between the mean scores on the 2003 ALT of CTA (code = 1) and of comparison (code = 0) groups exists because the mean score of the CTA group was less than the mean score of the comparison group. Students who had the lower mathematics scores from 8th grade tended to be placed into the CTA classrooms.

There is a very high negative correlation [$r = -.949$ (.95), $p \leq .001$] between previous math grade (from 8th grade) and relative assignment (or moving average) as shown in Table 12. The negative relationship exists because students in the CTA or treatment group were assigned a relative assignment treatment code whose mean was closer to the value of 1 than were students in the comparison group and the CTA group's mean 8th grade mathematics grades were lower than the grades of those students in the comparison group. Students with the lowest 8th grade mathematics scores were placed into the CTA classrooms.

There is a small, positive relationship between ELL status and ALT gain score with a correlation coefficient at .437 (r = .44) and $p \leq .01$ as identified in Table 12. ELL students (n = 71) were coded 1 if ELL and 0 if not designated with ELL status. ELL students tended to have greater ALT gains than non-ELL students.

Table 12

Correlations of Dependent Variables (ALT scores) with Selected Independent Variables

Depend. Var.		2003 ALT	2002 ALT	Prv. Grd.	RA[b]	Gen.[c]	Eth.	Diff.[d]
TrmtCde[a]	Pearson r	-.61	-.48	-.42	-.43	-.14	-.15	.14
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000
Prv.Grd	Pearson r	.30	.17	-	-.95	.21	-.13	.01
.	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.710
ELL[e]	Pearson r	-.14	-43	.03	.01	.01	.08	.44
	Sig. (2-tailed)	.000	.000	.393	.753	.669	.007	.000

Note. [a]n = 1027 for both groups

[b]Relative Assignment (moving averages)

[c]Gender was coded females: 1 and Males: 0

[d]Difference of gain between ALT 2002 and 2003

[e]n= 71--ELL Status coded 1; non-ELL status: 0

$p \leq .01$

Of the remaining independent variables displayed in Table 12, there is a significant relationship ($p = \leq .01$) between prior math grade and 2002 and 2003 ALT scores. The significant negative correlation of prior math grade with ALT 2002 ($r = -.43$) $p \leq .01$, validates the selection for placement into the CTA classrooms.

The researcher was also interested in knowing what simple correlations existed among selected classroom-level variables such as average ALT gain, percentage of ELL students in classrooms, percentage of female students in classrooms and classroom treatment condition. The Pearson Product Moment correlation statistic was used to estimate classroom-level relationships. Table 13 contains these correlation coefficients.

Table 13

Correlations of Classrooms-level Treatment Conditions with Selected Independent Variables

		Ave. Grade Dev.	Ave. Diff. In ALT Means	% of Fem.	% of ELL
Classroom Treatment Conditions [a]	Pearson r	-.77	.34	-.38	.44
	Sig. (2-tailed)	.000	.005	.001	.000

Note. CTA classrooms were coded: 1 and comparison classrooms were coded: 0

[a] N = 69 Classrooms

*$p \leq .01$

The high, negative correlation ($r = -.77$, $p \leq .01$) between the average grade deviation (from the "C" grade in 8th grade) and classroom assignment shows that students with lower grades from 8th grade tended to be placed in CTA classrooms. There is a low but statistically significant, positive relationship between classroom type (CTA/comparison) and classroom average gain scores on the ALT from 2002 to 2003 ($r = .34$, $p \leq 005$).

There is a low negative, but significant correlation ($r = -.38$, $p \leq .01$) between the percentage of females and classroom assignment. The percentage of females is greater in the comparison classrooms than in the CTA classrooms as shown in Table 14.

Table 14

Number of Classrooms that had Male and Female Majorities by Comparison and CTA (Treatment) Groups, 2002-2003

Classrooms	CTA (n)	Comparison (n)	Total (n)
Majority Male	23	10	33
Majority Female	9	23	32
Equal M and F	1	3	4
Total	33	36	69

The percentage of ELL status students in classrooms had a low positive ($r = .44$, $p \leq .01$) but significant correlation by CTA or comparison classrooms. Significantly more students of ELL status were in CTA classrooms than were in comparison classrooms.

The researcher was not only interested in the relationships of these independent variables to the dependent variables of pre and posttest ALT scores but also in the relative, predictive power of the independent variables. Based on the correlation coefficients, the researcher used a regression formula to answer the research question that focused on extent to which independent variables such as ELL status, gender and assignment to classroom groups can affect a change in ALT scores, which specifically addresses the null hypothesis.

Hierarchical Level Modeling

The hierarchical model (HLM) was used to address if classroom composition contributed to achievement outcome. The model consisted of three levels—time (pre and post treatment), student, and classroom. This HLM allowed the examination of how student-level relationships vary as a function of group characteristics. Variables retained in the final model were determined by a series of exploratory HLM analyses. The ALT scores were modeled with a series of regression-like, hierarchically nested equations where parameters from one level of analysis were analyzed at the next level of analysis (Nezlek & Zyzniewski, 1998). The Level 1 model (Time) is specified below:

Level 1 Model (Time)

$$Y = P0 + P1 * (YEAR) + E$$

The variable Y is an individual student's ALT score and the YEAR equals 0 in 2002 and 1 in 2003. Thus, Y is the 2002 ALT score when YEAR is 0 and the 2003 ALT score when the YEAR is 1.

The Level 2 or student-level Model is:

$$P0 = B00 + B01 * (GRADEV) + R0$$

P1 + B10 + B11 * (ASSIGN) + B12 * (GEN) + B13 * (ELL) + R1

In this equation, GRADEV is the prior 8th grade math grade (expressed numerically) minus 2, (centered about an average of C). ASSIGN is the moving average estimate of the assignment variable (which was a replacement for 0 and 1). GEN equals 1 if the student is female and 0 if male, and ELL is 1 if the student is ELL and 0 if not.

The Level 3 or classroom-level Model is as follows:

B00 = G00 + G001 (AVGRADEV) + U0

B01 = G010

B10 = G100 + G101 (CTA) + G102 (PCTELL) + U1

B11= G110

B12= G120

B13= G130

In the level 3 set of equations, AVGRADEV is the average of GRADEV in a given classroom. The treatment value equals 1 for CTA classrooms and 0 for the comparison classrooms. PCTELL is the percentage of ELL students in a given classroom. Table 15 displays the estimates of the regression coefficients and their standard errors for all three levels of the models for ALT scores.

The regression coefficient estimates shown in Table 15 are derived from the HLM analysis of the three-level regression model. The estimates represent the value of a dependent variable (ALT gain) in the five, predictor variables listed: CTA (the treatment), percent of ELL students in classrooms, classroom assignment, gender, and ELL status, which is expressed as a fraction of a standard deviation.

Table 15

Hierarchical Linear Model Explaining Variation in the Five Variables Affecting Student Achievement Using Pretest and Posttest ALT Gains, 2002-2003

	Fixed Effect	Coefficient	Std. Error	T-ratio	P-value
Classroom-Level	CTA	-0.545	0.924	-.590	0.555
	Percent of ELL students	0.084	0.048	1.734	0.083
Student-level	Classrooms Assignment (moving avg. estimate)	-1.888	1.441	-1.30	.190
	Gender	1.537	0.359	4.284	.000
	ELL Students	3.289	0.714	4.604	.000

Note. $^{*}p \leq .01$

Gender had a significant positive relationship ($p \leq .01$) with student achievement as measured by the ALT scores (coefficient = 1.537; *SE* = .359; *t*-ratio = 4.284). Student gender is a strong predictor for ALT score gains. At the student-level, ELL status had a significant positive relationship ($p \leq .01$) with student academic achievement gain as measured by the ALT scores (t-ratio = 4.604, *SE* = 0714; coefficient = 3.289).

In this study, ELL status is the strongest predictor of student achievement gain as measured by the ALT scores. The percentage of ELL students in classrooms, though not statistically significant ($p = .083$) is noteworthy.

Therefore, the researcher accepts the null hypothesis that the CTA program produces the same change in student achievement in developmental mathematics students as that in average and above students in comparison classrooms. However, the data reflect that CTA students *did* have higher gain scores as measured by the ALT. When controlling for other differences, the researcher found ELL status and being female as the strongest predictors for achievement gain in ALT scores.

Quantitative Results for Attitude

The researcher used sampling to measure student attitudes about mathematics in a pre-posttest design. From the data set of 1332 students and 69 classes, classrooms were randomly selected from among CTA and comparison groups—one classroom from each school respectively. A sample of 319 students received permission forms for participation. Of that group, 157 (49%) had pre-posttest surveys.

After the FSMAS pretest was given in April of 2003, four students moved; therefore, 153 students took *both* the pretest and posttest. Of that group, 81 students came from comparison and 72 students from CTA classrooms. The two scales (from the original 9 scales) employed were the Confidence Scale (CS) and the Attitudes Toward Success Scale (AS).

In building the final data set for the HLM analysis for the attitudes portion of the study, the researcher found that 26 students from the 153 students had other missing data (e.g., 2002 ALT pretest measure or prior math grade, etc.). Consequently, those 26 student records were eliminated.

In summary, the final HLM analysis that considered pre and posttest FSMAS resulted in only 127 students (once the 26 student records were eliminated). These 127 students had complete data sets-- 69 students from the comparison and 58 students from CTA classrooms. Table 16 displays the number of students who had complete data sets that were part of the HLM analysis for the FSMAS.

Table 16

Number of Students with Complete Data Sets for the HLM Analysis for FSMAS Data

Comparison Classroom ID	Students (n)	CTA Classroom ID	Students (n)	Total FSMAS Students (N)
10	10	1	10	
13	8	16	2	
26	6	19	6	
27	4	21	13	
51	8	39	9	
54	25	48	7	
61	8	56	4	
		67	7	
Total Comp. Students	69	Total CTA Students	58	127

There were too few students in the sample using HLM to address the possibility of classroom composition contributing to a change in student attitudes on the CS and AS from the FSMAS. Therefore, the attitudes null hypothesis was not tested.

At the student level, the researcher compared the means of students (n = 58) in the CTA classes with those students (n = 69) in comparison classes (See Appendix B). A matched-pair samples *t*-test yielded non-significant results for both the CS and AS surveys. The researcher accepts the null hypothesis for attitudes that states the CTA program produces the same change in students' attitudes toward mathematics in developmental mathematics students as that in average and above average students in a comparison group as measured by the FSMAS.

Summary

The researcher examined the number of students who were assigned to each study group. A Chi Square analysis determined that there was a significant departure from the strict assignment of students into CTA and comparison classrooms. The researcher used a relative assignment as an analytic adjustment to the *fuzzy* assignment.

The means on the 2002 and 2003 ALT were disaggregated by various independent variables. The Pearson Correlation was used to identify significant relationships between the 2002 and 2003 ALT gain and various independent variables. An HLM analysis addressed the possibility of classroom composition contributing the achievement outcome. The HLM technique yielded significant results for gender and ELL status as predictive variables for ALT achievement gain.

Chapter V contains a summary of the findings and conclusions. The researcher outlines recommendations for future study, implications for ELL learners, and policy initiatives.

CHAPTER V

SUMMARY of FINDINGS, CONCLUSIONS, and RECOMMENDATIONS

Introduction and Review of Purpose

This chapter presents a summary of the findings, conclusions, and recommendations for future research, policy issues and mathematics teaching practices. The researcher discusses the data analyzed from the 2002 and 2003 Achievement Levels Test (ALT) and the Fennema-Sherman Mathematics Attitudes Scales (FSMAS) along with pertinent conclusions.

The purpose of this study was to compare and analyze the achievement and attitude results of developmental-mathematics students (n = 559) who used a technology-based algebra program, the Cognitive Tutor Algebra (CTA) in treatment or CTA classrooms (n = 33) with a representative sample of average and above average students (n = 468) in comparison classrooms (n = 36). Class sizes were roughly equivalent in both groups with approximately 23[1] students in each classroom.

[1] There were advanced eighth graders assigned to several comparison classrooms. Those students were excluded from the study but were part of the calculation for class size averages.

Over the past 20 to 30 years, meta-analyses have been done to examine the effects of technology on student outcomes. Niemiec and Walberg (as cited in Waxman, Connett, and Gray, 2002) and Christmann and Badgett (1997) demonstrated that there is a positive, significant effect on student learning using technology. There is conflicting evidence, however, in the research regarding effective ways technology is used in the learning process.

Wenglinsky (1998) reported that when technology is used for drill and practice, students lose grade-level growth. However, Koedinger, Alibali and Nathan (1999) claimed student success is achieved when technology is used to assist developmental-mathematics students in mathematics classrooms with grounded representations of abstract ideas using story problems in a digital environment.

The effects on student achievement using technology-based systems such as Computer Algebra Systems (CAS) and the Computer Assisted Instruction (CAI) are well documented in the literature. Palmiter (1991) found the use of CAS to significantly impact mathematics instruction. Goetzfried and Hannafin (1985) found mixed results in below-average and low-achieving students. The researchers found a significant difference in instructional time using CAI with students designated as below-average, but non-significant findings with those students classified as low-achieving.

With respect to lower-ability mathematics students, research suggests that while students may be able to memorize and apply algebraic algorithms, many do not understand how the symbolic representations apply to real-life mathematical problems. Research suggests that lower-ability mathematics students benefit from a "bridge" that provides concrete understanding of algebraic symbols and equations (Brenner, et al., 1997; Koedinger, Alibali & Nathan, 1999; and Mayes, 1995).

Regarding student attitudes, Ma (1997) reported that meta-analyses confirmed a more positive attitude toward mathematics (ATM) contributes to a higher level of achievement in mathematics (AIM). Pierce and Stacey (2001) suggested that students' attitudes toward the use of CAS for learning mathematics were positive; however, their study did not conclude that there was a demonstrable change in student achievement resulting from use of computer tools to teach algebra. Ma and Kishor (1997) conducted a meta-analysis concerning ATM. Using effect size (ES) to measure variables from 113 studies, their research suggested that ATM is more closely associated with secondary students than with elementary students.

Summary of Research Design

The present study employed a quasi-experimental design with nonequivalent control groups. To select students into study groups, a cut-off score was used therefore necessitating a regression-discontinuity design. The two groups, CTA (treatment) and comparison, consisted of all ninth-grade students (N = 1027) enrolled in algebra courses at each of the district's seven junior high schools in addition to the ninth-grade class at the district's K-12 alternative setting.

The CTA group (n = 559) mainly consisted of developmental-mathematics students defined as students having received grades of "C-","Ds" or "Fs" from their eighth-grade mathematics course and who received instruction in a technology-based classroom environment in the ninth-grade. The comparison group (n = 468) mainly consisted of average and above average students having received grades of "As", "Bs" or "C+" from their eighth-grade mathematics course. Students who received grades of "C" were able to self-select either group.

However, 24% (n = 249) of all students were mis-assigned into study groups. The researcher conducted a chi square test for association and found the departure significant ($p \leq .001$) from the strict or intended, ninth-grade assignment. A standardized residual of -4.9 was observed for the number of students who should have been assigned into comparison classrooms, and a standardized residual of 5.7 was observed for the number of students who should have been assigned into CTA classrooms.

Because of the significant department from the intended assignment into study groups, an analytic adjustment was made. This adjustment or "moving average" was used in the Hierarchical Lineal Model (HLM) analyses as part of the regression-discontinuity design to determine which independent variables had a predictive relationship to student achievement gain as measured by the 2002 and 2003 ALT scores. The moving averages, used as an independent variable in the Pearson *r* statistic, measured the strength of relationships between selected independent variables.

Review of Findings and Interpretations for Achievement

The null hypothesis for achievement stated that the CTA program produces the same change in achievement in developmental-mathematics students as that in average and above students in a comparison group as measured by the ALT for algebra. The researcher used HLM to address the possibility of classroom composition contributing to the achievement outcome.

The three-level modeling technique allowed the examination of how student-level relationships vary as a function of group characteristics. Using the generally accepted .05 level of significance for social science research (Hinkle, Wiersma & Jurs, 2003), the researcher accepts the achievement null hypothesis though the data would reflect that CTA students did have significantly higher gain scores than did students in comparison classrooms when controlling for other factors.

At the classroom level, the *HLM* analysis showed the CTA program to have a non-significant, predictive relationship (p = .56) with student academic achievement as measured by ALT scores. However, the CTA students had a higher mean gain (M = 12.7) on pre-posttest ALT than did comparison students who had a mean gain of 9.4.

One possible explanation of this non-significant analysis at the classroom level may be that 24% of students were mis-assigned into study groups even though an analytic adjustment for this fuzzy assignment was employed. Nearly 31% of students (n = 171) assigned to the treatment (CTA) classrooms should have been assigned to comparison classrooms; conversely, 17% of students (n = 78) assigned to comparison classrooms should have been assigned to CTA classrooms.

Furthermore, the analytic adjustment did contribute to a lower reliability estimate which was factored into the HLM formula and may have contributed to the non-significant findings for the CTA program at the classroom level. Further research is needed using a random sample and control-group design to shed added light on the effectiveness of the CTA program for developmental (or lower-ability) mathematics students.

The researcher conjectures that one possible explanation for the significant departure from the intended assignments into study group may be explained by the "Expert Blind Spot" hypothesis (Nathan & Petrosino, 2004). Nearly 31% of student (n = 171) should have been assigned to CTA classrooms. These students received grades of As and Bs and should have been assigned to comparison classrooms.

Teachers ignored these grades and mis-assigned students into CTA classrooms. Nathan and Petrosino (2004) contend that educators with advanced subject-matter knowledge "may think about their algebra students through a math-centric lens" (p. 910). The math-centric focus may have contributed to the number of students mis-assigned into both study groups. Consequently, the researcher needed to factor an analytic adjustment into the HLM formula which may have contributed to non-significant findings at the classroom level.

Finding the CTA program in this study to have a non-significant, but positive, predictive relationship to student achievement is consistent with one other study of the CTA program using a non-equivalent control group design. That ninth-grade study compared achievement results of algebra students (n = 229) in experimental classrooms using the CTA program with students (n = 216) in comparison classrooms where traditional algebra textbooks were used (Smith, 2001).

The present non-significant findings are in contrast to the Koedinger et al., (1997) CTA study. In that study, students who participated in the CTA program (n = 470) outperformed students in the comparison classrooms (n = 120) on the Iowa Algebra Aptitude Test and two problem-based assessments developed by the authors ($p \leq .05$). These researchers, however, may have had a vested interest in the outcome of the study, as they assisted in the authoring of the program.

The HLM analysis showed the percentage of ELL students assigned to CTA classrooms was a positive, standardized beta at .08 (t = 1.73, p = .08), though not statistically significant but noteworthy. There were nearly four times as many ELL students assigned to CTA classrooms (*n* = 58) as were assigned to comparison classrooms (*n* = 13). The Pearson *r* statistic confirmed a statistically significant relationship ($r = .4$, $p \leq .01$) with being designed as ELL and being assigned into the CTA classrooms.

The most significant finding from the HLM analysis at the student level showed that the largest weight (coefficient) was associated with students being designated as English Language Learner (ELL) status. The standardized beta was 3.289 ($t = 4.28$, $p \leq .000$). In an examination of means, ELL students in CTA classrooms (*n* = 58) had the greatest ALT mean gain (*M* = 31.97) as compared with ELL students in comparison classrooms (*M* = 17.61). Non-ELL students in both comparison and CTA classrooms had an average ALT gain of 9.8.

The HLM analysis showed that gender had a statistically positive and predictive relationship ($p \leq .001$) with achievement gain scores as measured by the ALT. A few more females were in comparison classrooms (*n* = 268) than were assigned into CTA classrooms (*n* = 242). In an examination of means on the pre-posttest ALT, females not only had higher mean scores in 2003 (*M* = 247.6) as compared to males (*M* = 244.7), but females also had higher gain scores (*M* = 12.1) as compared to males (*M* = 10.2).

Females in the CTA program (n = 242) had the greatest gain in mean scores when compared to females in comparison classrooms (n = 268) or males in both study groups (n = 517). Females in the CTA program gained 13.75 Rasch or RIT units as compared with the males in the CTA program (n = 317) whose gain score was 11.84.

Males in the CTA program (n = 317) had a gain score of 11.84 in contrast to males in the comparison classrooms (n = 200) whose ALT gain was 7.66. A paired samples t-test showed that each of the paired differences were significant at ($p \leq .000$). However, gender per se may not be producing the significant difference. The difference may be due to how students were assigned to CTA classrooms or that lower-ability students tend to learn from involvement and manipulation of their learning through the use of technology. The hierarchical nature of the data may also be a contributing factor.

These findings appears to be congruent with other research conducted by Frost, Hyde and Fennema (1994) which indicted that females did as well as males or better in algebra, arithmetic and computation. Note, however, that more males were placed into CTA classrooms (n = 317) than into comparison classroom (n = 200). Analyses of gender differences on mathematics tests have recently moved from simply comparing mean differences on particular tests to analyzing gender performance on specific test items (Garner & Engelhard, 1999).

There was an added complicating factor in interpretation on gender differences and ALT performance in this study of 1027 students. Students who had accelerated mathematics in grades seven and/or eight were excluded in the population. Advanced ninth-grade mathematics students excluded from the study included 283 males and 283 females. There were slightly more males (n = 800) than females (n = 793) in the entire ninth-grade cohort of students including CTA, comparison and advanced-level mathematics students.

While students assigned to the CTA program made considerable gains in achievement as measured by the ALT, the HLM analysis did not show statistical significance for the CTA program. The efficacy of such a conclusion must take into account the delimitations and limitations placed on this study.

Review of Findings and Interpretations for Attitudes

Two FSMAS scales were selected for the attitudes portion of the study- a Confidence Scale (CS) and the Attitudes Toward Success Scale (AS). A retrospective pre-test and a posttest was administered to 153 students from both the treatment (CTA) and comparison classrooms-one classroom from each school (n = 8). When the final data set for HLM was constructed, 26 students had missing data; consequently, the final ALT analysis was conducted using a smaller sample of CTA students (n = 58) and comparison students (n = 69). There were too few students to address the possibility of classrooms composition contributing to a change in student attitudes on the CS and AS using HLM. The null hypothesis was not tested. A matched pair t-test was used to measure individual student attitudes on this small sample which led to non-significant results.

Conclusions

The researcher hypothesized that a technology-based program (CTA) would have the same effect on achievement of developmental mathematics students as compared to a comparison group. Though statistically significant gain scores were observed with ELL students, the results of the HLM analysis demonstrated a non-significant predictive relationship to a gain in academic achievement as a result of the treatment of the CTA program. However, ALT gains were evident in nearly every demographic group in CTA classrooms as compared to students in those same demographic groups in comparison classrooms. Additionally, most students in the treatment classrooms (CTA) would not have had access to high school algebra if the CTA program had not been assigned. Therefore, these findings should consider the limitations and delimitations placed on this study.

Using a quasi-experimental research design, the most significant limitation was the mis-assignment of students into groups. Optimal research would have employed randomness using experimental and control groups. Mis-assignment may have been due to a lack of knowledge about the CTA program on the part of key individuals in each the schools at the onset of the study (e.g., counselors, teachers, and principals who had some influence on assignment) in addition to the "Expert Blind Spot" hypothesis (Nathan & Petrosino, 2004).

The researcher could have used other analytic adjustments to mitigate the fuzzy assignment into study groups. For example, the reliability estimates on the posttest ALT gain scores might have increased when different analytic adjustments were used. Additionally, the researcher did not consider the elimination of those students who were mis-assigned into study groups. If the relative assignments were removed from the formula, the HLM analyses might have produced significantly different results.

This non-significant finding may also be due to the instrumentation used to measure student performance. The effectiveness of CTA program may have been masked by the ALT instrumentation used. The CTA program uses problem-based learning to assist students with knowledge on how to apply the algebraic concepts presented. The paper-pencil tasks and forced response format of the ALT may have masked some of the effectiveness of the CTA program.

While misalignment of instrumentation used to measure program effectiveness of the CTA curriculum may exist, ELL students did show the greatest pre-posttest gain of any demographic group (M = 31.97). The data suggest that ELL students may benefit from being grouped into classrooms with other ELL students or from being in CTA classrooms. Further research is needed to follow the cohort of students who were assigned into CTA classrooms on their performance on the 10th grade Washington Assessment of Student Learning (WASL) which incorporates many open-ended, student-constructed responses that are similar to the format to the CTA curriculum.

Evidence from the study provides school district officials with knowledge that ELL students can benefit from the technology-based algebra program. Lower-level mathematics courses, below algebra, might be discontinued for a large segment of this population.

An additional delimitation that may have contributed to the outcome was that the researcher had no influence in the selection of the teachers who would teach the CTA groups. No survey or interview selected the most technology-savvy instructors to teach the CTA program. No evidence was collected to determine the degree of preparedness on the part of CTA instructors to teach using *technology-in-the-classroom* (CTA) as a major component of the instructional process. Future research should include teacher attitudes regarding the use of technology in the classroom.

With respect to the attitudes portion of the study, the Fennema-Sherman Mathematics Attitude Survey (FSMAS) has over two decades of research along with a body of evidence that measures student attitudes toward math. The lack of statistically significant findings may relate to the number of pre-post surveys returned (n = 157). In retrospect, the researcher could have enlarged the sample of students selected to take the FSMAS.

With enough time, the researcher would not have employed a retrospective pretest to measure student attitudes about mathematics. Such retrospection on the part of students may have been an influential factor in the non-significant results.

In summary, there were remarkable achievement gains made by various groups in this study. In light of high-stakes testing, increases in graduation requirements, and providing a gateway to community or technical college for underrepresented populations, the findings are significant on that fact alone. Future research in this area, while controlling for the issues identified, is needed particularly in light of the ever-changing demographics of American public schools today.

Recommendations for Practice and Policy

The capacity to create new opportunities for students and teachers through the use of real-world problems and contexts is an important use of technology in the classrooms today (Bransford, et al., 2000). Furthermore, the role that technology has played in the curriculum since the 1980s is changing. Early digitized curricula simply automated the textbook drill-and-practice. Evidence from the CTA program showed that students can become independent learners using a technology-assisted, problem-based approach to high school-level algebra. The researcher recommends that the CTA program be made available to all type of learners with particular emphasis on lower-ability and ELL status students.

This study reveals that students in particular program areas may need a 1:1 ratio of computers to students. School systems should reevaluate the computer ratio formulae common in many public schools to align technology-based learning with the number of computers needed. For example, each student in the CTA program needed computer access in a 1:1 ratio 40% of the instructional time as part of his/her algebra coursework. This may influence how many computers high schools need.

In summary, study results support that the school district's decision to require algebra and geometry of all students by tenth-grade. The district made available two mathematics courses-the use of an alternative, student-centered, technology-based algebra course (CTA) along with a traditional algebra format. Study results suggest that *all* students can benefit from varied learning environments.

The researcher recommends that the CTA version of geometry be considered as a second course in the sequence of mathematics courses prior to students taking the tenth-grade WASL. This second course may ensure that students who met with success in the CTA program will have a similar learning environment for geometry.

Recommendations for Future Research

Prior to the implementation of the CTA program in the district, lower-ability, ninth-grade students were enrolled in courses below algebra. Some students took two or more years of mathematics courses and still did not reach the level of algebra. Even though the CTA program had non-significant findings, future research on developmental or lower-ability mathematics students could include a variety of mathematics programs. Such a study could highlight which program or teaching methodologies might best address the needs of particular types of learners (e.g., ELL, males, developmental mathematics students, etc.).

Based on the significant findings concerning achievement of ELL students, a future study could identify which demographic groups of ELL learners benefit the most (e.g., males, Latinos, African, eastern European, etc.). Research in this area could identify how ELL students may be acquiring the requisite English-language skills needed to be successful in a language-intensive environment while learning mathematics. The researcher found many topics deserving further study during informal classroom observations throughout the implementation of the CTA program (Appendix E).

The fact that there were more males assigned to CTA classrooms than females deserves further study. Do males prefer technology-based learning? If so, what are the characteristics of those boys? Do females prefer the cooperative-learning environment that CTA provides in the computer portion of the course? What impact do these variables have on student achievement?

A number of issues need to be addressed as technology environments are increasing and changing. The investigation of the interactivity between students and machines is in its infancy. More study is needed to learn if educators are harnessing technology in appropriate, meaningful ways.

Final Notes

The researcher has keen interest in the educational opportunities afforded to students who are sometimes found at the margins of educational practice. The present study contributes to the research base by providing evidence that developmental students learn in different ways.

This study helped to illuminate for mathematics teachers that students have capacities for learning far beyond what may seem apparent. Perhaps the technology propelled some and engaged others or perhaps the concrete representations helped as students developed algebraic sense through real-life, authentic problems in the CTA program. In either event, research in this field is needed to identify for educators and researchers the best instructional practices in the teaching of high school algebra.

REFERENCES

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How People Learn.* Washington, D.C.: National Academy Press.

Brenner, M. E., Mayer, R. E., Mosley, B., Brar, T., Durán, R., Reed, B. S., et al. (1997). Learning by understanding: The role of multiple representations in learning algebra. *American Educational Research Journal,* 34*(4),* 663-689.

Bryk, A. S.& Raudenbush, S. W. (1992). *Hierarchical linear models: Applications and data analysis methods.* Thousand Oaks, CA: Sage Publications.

Burrill, G., (1997). Algebra for the twenty-first century: A new vision. *NASSP Bulletin, 81*(586), 11-16.

Butzin, S. M., (2001). Using instructional technology in transformed learning environments: An evaluation of project CHILD. *Journal of Research on Computing in Education, 33*(4), 367-373.

Campbell, D., & Stanley, J. (1963). *Experimental and quasi-experimental designs for research.* Chicago: Rand McNally.

Carter, C. M., & Smith, L. R. (2000). *Does the use of learning logic in Algebra I make a difference in Algebra II?* (ERIC Document Reproduction Service No. ED 444 868).

Christmann, E., & Badgett, J. (1997). Progressive comparison of the effects of computer-assisted instruction on the academic achievement of secondary students. *Journal of Research on Computing in Education, 29(4)*, 325-337.

Fendel, D., Resek,D., Fraser, S., & Alper, L. (1997). What is the place of algebra in the K-12 mathematics program? *NASSP Bulletin, 81,* 60-64.

Fennema, E., & Sherman, J. (1976). Fennema-Sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *JSAS Catalog of Selected Documents in Psychology, 6,*31 (Ms. No. 1225).

Forgasz, H. J., Leder, G. C.,& Gardner, P. L., (1999). The Fennema-Sherman mathematics as a male domain scale reexamined. *Journal for Research in Mathematics Education, 30* (3).

Frost, L. A., Hyde, J. S., & Fennema, E. (1994). Gender, mathematics performance , and mathematics-related attitudes and affect: A meta-analytic synthesis. *International Journal of Educational Research, 21,* 373-384.

Garner, M., & Engelhard, Jr., G. (1999). Gender differences in performance on multiple-choice and constructed response mathematics items. *Applied Measurement in Education, 12*(1), 29-51.

Glickman, C. L., & Dixon, J. K. (2002). Teaching intermediate algebra using reform computer assisted instruction. *The International Journal of Computer Algebra in Mathematics Education, 9,* 75-89.

Godwin, K., & Sheard, W. (2001). Education reform and the politics of 2000. *Publius, 31,* 111-132.

Goetzfried, L., & Hannafin, M. J. (1985). The effect of the locus of CAI control strategies on the learning of mathematics rules. *American Educational Research Journal, 22(2), 273-278.*

Hall, D. (2002, May). Teachers and Technology. Unpublished Technical Report. Kent School District. Kent, WA.

Heid, M.K. (1998, June). *The impact of computing technology on the teaching and learning of mathematics at the secondary level: Implications for Standards 2000.* Paper presented at the meeting of NCTM Standards Technology Conference. Retrieved January 29, 2004 from http://mathforum.org/technology/papers/papers/heid/heid.html

Heid, M. K., & Zbiek, R. M. (1995). A technology-intensive approach to algebra. *The Mathematics Teacher, 88* (8), 650-66.

Hinkle, D. E., William, W., & Jurs, S. G. (2003). *Applied statistics for the behavioral science.* Boston, MA: Houghton Mifflin Company.

Hubbard, L., (2000). Technology-based math curriculums. *Technological Horizons in Education Journal, 28,* (3), 80-87.

Ingebo, G. S. (1997). *Probability in the measure of achievement*. Chicago: MESA Press.

Jitendra, A., & Xin, Y. P. (1997). Mathematical word-problem-solving instruction for students with mild disabilities and students at risk for math failure: A research synthesis. *Journal of Special Education, 30,* 412-438.

Koedinger, K. R., Alibali, M. W., & Nathan, M. J. (1999). *A developmental model of algebra problem solving: Trade-offs between grounded and abstract representations.* (ERIC Document Reproduction Service No. ED 433 245).

Koedinger, K. R., Anderson, J. R., Hadley, W. H., & Mark, M. A. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education, 8, 30-43.*

Lawson, J. L., & Chinnappan, M. (2000). Knowledge connectedness in geometry problem solving. *Journal for Research in Mathematics Education, 31*(1), 26-43.

Ma, X. (1997). Reciprocal relationships between attitude toward mathematics and achievement in mathematics. *Journal of Educational Research, 90,* 221-229.

Ma, X., & Kishor, N. (1997). Assessing the relationship between attitude toward mathematics and achievement in mathematics: A meta-analysis. *Journal for Research in Mathematics Education, 28* (1), 26-47.

Mathews, J. (2002, August 18). Algebra poses a problem of timing. *Washington Post*. Retrieved September 10, 2002, from http://www.washingtonpost.com

Mayes, R. L. (1995). The Application of a computer algebra system as a tool in college Algebra. *School Science and Mathematics, 95,* 61-68.

Melancon, J.G., Thompson, B., & Becnel, S. (1994). Measurement integrity of scores from the Fennema-Sherman Mathematics Attitudes Scales: The attitudes of public school teachers. *Educational and Psychological Measurement, 54* (1), 187-192.

Mullis, I. V., Martin, M. O., Beaton, A. E., Gonzales, E. J., Kelly, D. L., & Smith, T. A. (1998). *Mathematics and science achievement in the final year of secondary school.* Chestnut Hill, MA: Boston College.

Nathan, M. J., & Petrosino, A., (2004). Expert blind spot among preservice teachers. *American Educational Research Journal, 40* (4), 905-928.

National Center for Education Statistics. (1995). Third International Mathematics and Science Study, [Data file]. Available from U.S. Department of Education Web site: http://nces.ed.gov/timess95/index.asp.

National Center for Education Statistics. (1998). *Pursuing excellence: A study of twelfth grade mathematics and science achievement in international context.* Washington, DC: Education Publication Center.

National Center for Educational Statistics. (1999). *Highlights from TIMMS.* Retrieved August 20, 2003 from: http://nces.ed.gov/pubs99/1999081.pdf.

National Center for Education Statistics. (2001). *The Nation's Report Card: Mathematics 2000.* (NCES 2001-517). Washington, DC: Education Publication Center.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

National Education Goals Panel. (1989). *Report of the National Education Goals Panel.* Washington, DC: U.S. Government Printing Office.

Nezlek, J. B.& Zyzniewski, L. E. (1998). Using hierarchical linear modeling to analyze grouped data.[Electronic version.] *Group Dynamics, 2* (4), 313-320.

Northwest Evaluation Association. (2002). *RIT scale norms.* (2002 ed.). Portland, OR: Author.

Northwest Evaluation Association. (2003). *Glossary of Terms from NWEA Website*. Retrieved October 10, 2003, from: http://www.nwea.org/MainPages/glossaryofterms.htm#top.

Oakes, J. (1995). Opportunity to learn: Can standards-based reform be equity-based reform? In I.M. Carl (Ed.), *Prospects for School Mathematics.* Reston, VA: National Council of Teachers of Mathematics, 78-79.

Palmiter, J. R., (1991). Effects of computer algebra systems on concept and skill acquisition in calculus. *Journal for Research in Mathematics Education, 22* (2), 151-56.

Pierce, R., & Stacey, K. (2001). Reflections on the changing pedagogical use of computer algebra systems: Assistance for doing or learning mathematics? *Journal of Computers in Mathematics and Science Teaching, 20,* 143-154.

Pugalee, D. K. (2001). Algebra for all: The role of technology and constructivism in an algebra course for at-risk students. *Preventing School Failure, 45*(4), 171-177.

Reyes, L. H. (1984). Affective variables and mathematics education. *Elementary School Journal, 84,* 558-581.

Rothstein, R., (2002, January). *Out of balance: Our understanding of how schools affect society and how society affects schools.* The Spencer Foundation 30th Anniversary Conference.

Schofield, J. W., Eurich-Fulcer, R., & Britt, C. L. (1994). Teachers, computer tutors, and teaching: *The artificially intelligent tutor as an agent for classroom change, 31(3), 579-607.*

Schultz, J. E., & Nogurea, N. (2000). High level technology in a low level mathematics course. *The International Journal of Computer Algebra in Mathematics Education,* 7(1), 25-30.

Smith, J. E. (2001). *The effect of the carnegie algebra tutor on student achievement and attitude in introductory high school algebra.* (Unpublished doctoral dissertation, Virginia Polytechnic Institute and State University, Blacksburg).

Steen, L. A., (2002). Achieving mathematical proficiency for all. *The College Board Review, 196,* 4-11.

Telese, J. A. (1999). *The role of social constructivist philosophy in the teaching of school algebra and in the preparation of mathematics teachers.* (ERIC Document Reproduction Service No. ED 432 469).

Trochim, W. M. K. (1984). *Research design for program evaluation: The regression-discontinuity approach.* Beverly Hills, CA: Sage Publications.

U.S. Department of Education. (2000). *Before it's too late.* Retrieved July 29, 2002: www.ed.gov/americacounts/glenn.

Valasquez, C. N. (2003). *The basics of regression-discontinuity designs*. Retrieved October 11, 2003, from: http://trochim.human.cornell.edu/tutorial/nieves/rddesign.htm

Waxman, H. C., Connell, M. L., & Gray, J. (2002). *A quantitative synthesis of recent research on the effects of teaching and learning with technology on student outcomes*. Retrieved January 4, 2004, from: http://www.ncrel.org/tech/effects/effects.pdf

Wenglinsky, H. (1998). *Does it compute? The relationship between educational technology and student achievement in mathematics*. Princeton, NJ: Educational Testing Service.

APPENDIXES

APPENDIX A

Preliminary Statistical Analysis on Achievement

In a preliminary analysis, the researcher used a dependent matched-pair sample *t* test to compare means on the 2002 and 2003 ALT and found that the two means were significantly different ($p \leq .000$) with a positive *t* value of 31. 61. As stated in Chapter IV, the *t*-statistic tested the significance of a biased estimate of the CTA treatment effect as this bias stemmed from the failure to consider the way students were assigned to the CTA classrooms and the hierarchical nature of the data.

Table A1

2002-2003 ALT Paired Samples Statistics

		Mean	N	SD	SE Mean
Pair 1	2003 ALT	246.16	1027	8.62	.27
	2002 ALT	234.98	1027	14.40	.45

Table A2

2002-2003 ALT Paired Samples Test

	Mean	SD	SE Mean	t	df	Sig. (2-tailed)
Pair 1 2003- 2003 ALT	11.19	11.34	.354	31.61	1026	.000

APPENDIX B

Preliminary Statistical Analysis on Attitudes using FSMAS

In a preliminary analysis, the researcher used a dependent matched-pair sample *t* test to compare means on the two scales from the FSMAS pre and posttest FSMAS. The Attitude Scale (AS) and the Confidence Scales (CS) were used to measure student attitudes about mathematics.

In the sample, there were 127 students who had both pre and posttest results on the AS and on the CS from the FSMAS in addition to having complete data sets (e.g., pre and post ALT, prior math grade, etc.). These 127 students were divided as follows-- 69 students from comparison and 58 students from treatment classrooms. In examining the results from the AS in Table B2, the researcher found that the two means were non-significant.

Table B1

Pre and Posttest AS from FSMAS Paired Samples Statistics

Study Groups			Mean	N	SD	SE Mean
Comparison	Pair 1	AS Pre	49.33	69	7.79	.94
		AS Post	47.90	69	8.74	1.05
Treatment	Pair 1	AS Pre	47.26	58	8.19	1.08
		AS Post	46.43	58	9.82	1.29

Table B2

Pre and Posttest AS from FSMAS Paired Samples Test

Study Groups		Mean	SD	SE Mean	t	df	Sig. (2-tailed)
Comp.	Pair 1 AS Pre-AS Post	1.43	7.95	.96	1.50	68	.139
Treat.	Pair 1 AS Pre-AS Post	.83	11.87	1.56	.531	57	.597

In examining the results from the CS in Table B3, the researcher found that the two means were non-significant.

Table B3

Pre and Posttest CS from FSMAS Paired Samples Statistics

Study Groups			Mean	N	SD	SE Mean
Comparison	Pair 1	CS Pre	40.94	69	11.58	1.39
		CS Post	41.52	69	11.07	1.33
Treatment	Pair 1	CS Pre	38.76	58	11.98	1.57
		CS Post	40.41	58	11.68	1.53

Table B4

Pre and Posttest CS from FSMAS Paired Samples Test

Study Groups		Mean	SD	SE Mean	t	df	Sig. (2-tailed)
Comp.	Pair 1 CS Pre-CS Post	-.58	10.41	1.25	-.462	68	.645
Treat.	Pair 1 CS Pre-CS Post	-1.66	9.99	1.31	-1.26	57	.212

Appendix C

Analysis on ALT Gain by Gender and Treatment Condition

The researcher used a dependent matched-pair sample *t* test to compare means on the 2002 and 2003 ALT by treatment condition and gender. All paired differences were significantly different ($p \leq .000$) with a positive *t* values. As stated in Chapter IV, the *t*-statistic tested the significance of a biased estimate of the CTA treatment effect as this bias stemmed from the failure to consider the way students were assigned to the CTA classrooms and the hierarchical nature of the data.

Table C1

2002-2003 ALT Paired Samples Statistics by Gender and Treatment Condition

Gender	Treatment		Mean	N	SD	SE Mean
Male	Pair 1					
	Comparison					
		2003 ALT	250.85	200	7.44	.53
		2002 ALT	243.20	200	8.21	.58
	CTA					
		2003 ALT	240.85	317	7.11	.40
		2002 ALT	229.01	317	14.10	.79
Female	Pair 1					
	Comparison					
		2003 ALT	252.65	268	6.99	.43
		2002 ALT	241.91	268	9.67	.59
	CTA					
		2003 ALT	242.08	268	5.71	.37
		2002 ALT	228.33	268	16.23	1.04

Table C2

2002-2003 ALT Paired Samples Test by Gender and Treatment Condition

Gender	Treatment	M	SD	SE Mean	t	df	Sig. (2-tailed)
Male	Pair 1 Comparison 2003-2003	7.66	7.41	.53	14.6	199	.000
	CTA 2003-2003	11.84	12.26	.69	17.2	316	.000
Female	Pair 1 Comparison 2003-2003	10.74	8.36	.51	21.0	267	.000
	CTA 2003-2003	13.75	14.48	.93	14.8	241	.000

APPENDIX D

Scope and Sequence of Algebra I and Algebra Cognitive Tutor

Algebra I	**Algebra Cognitive Tutor**
Tools of Algebra	Patterns and Linear Functions
Functions and Their Graphs	Proportional Reasoning and Linear Functions
Algebraic Concepts and Simple Equations	Modeling Situations Using Multiple Representations
Equations and Inequalities	Linear Equations and Systems of Equations
Graphing and Writing Linear Equations	Statistical Analysis
Systems of equations and Inequalities	Quadratics
Quadratic Equations and Functions	Laws of Powers
Right Triangles and Radical Expressions	
Polynomials	
Rational Expressions and Functions	

APPENDIX E

Sample of Entries from Field Notes

The researcher took field notes as he visited 12 of the 33 CTA classrooms during the 2002-2003 school year. Teachers, counselors and school principals provided the researcher with anecdotes and unsolicited commentary on the implementation of the CTA program. The comments follow the chronology from the researcher's field notebook:

- The initial reaction from teachers and counselors was a negative one regarding having ELL students assigned to a technology-based program that required reading story problems.
- Many mathematics teachers and counselors initially believed that ELL students lacked the basic understanding of the English language to assist them in learning algebra.
- ELL students are learning English skills due to the required reading. Other students help ELL students when necessary. ELL students seem to benefit (as an unintended consequence) from reading the story problems and applying numbers to the variables.
- The CTA teacher's role in the computer lab portion changed from lecturer to "coach" and "facilitator."

- Staff development needs to be designed to assist staff in making the shift "from standing in the front of a room lecturing to students" to assisting, coaching, and assessing individual students.
- The computer lab portion of the CTA program is "natural" cooperative learning. Students do not want to lose the gold bars on the program screen. They naturally ask each other for help.
- Teachers do not know how to engage students in cooperative groups during the classroom portion of the program. Many instructors want training to teach them how to sustain cooperative learning throughout all aspects of the course.

APPENDIX G

Student Assent

Researcher
Gary S. Plano, Doctoral Student at Seton Hall University, College of Education and Human Services, Department of Education, Leadership, Management and Policy, Executive Doctoral Program

Purpose of Research
The purpose of this research project is to examine the effects that the *Cognitive Tutor Algebra* program, a program used in some 9th grade algebra classes, has on student achievement and on student attitudes about math.

Description of Procedures

There is a short survey called the Fennema-Sherman Mathematics Attitudes Scales that will be presented to students. I understand that I will be asked about my general attitudes about mathematics and the degree of confidence I have around math topics. The survey will take approximately 15 minutes. It will be given once in the spring and again in June. In addition to the survey, my test results from the Achievement Levels Test and the Iowa Test of Educational Development, both district-directed tests, will be used.

Participation

This is strictly voluntary, and I understand that I may withdraw at any time. There will be no penalty or loss of any kind should I choose not to participate or withdraw. I realize that an alternate class assignment will be provided in the event I choose not to participate.

Anonymity

Student data will be collected using Kent School District's student identification system which consists of numeric digits only. No student will be identified by name. No individual student data will be identified or will any student be named in the research project. Anonymity will be maintained throughout.

Confidentiality and Security

Information will be stored in the researcher's home. The data will be destroyed three (3) years after the completion of the project. Data will only be reported by class and not by student identifiers.

Risks

There are no foreseeable risks to you concerning your answers to questions about your attitudes about math.

Benefits

There are no expected direct benefits to you; however, researchers and others may have interests in how you perceive mathematics-- particularly algebra.

This project has been reviewed and approved by the Seton Hall University Institutional Review Board for Human Subjects Research. The IRB believes that the research procedures adequately safeguard the subject's privacy, welfare, civil liberties, and rights. The Chairperson of the IRB may be reached through the Office of Grants and Research Service. The telephone number of the Office is (973) 275-2974.

I have read the material above, and any questions I asked have been answered to my satisfaction. I agree to participate in this activity, realizing that I may withdraw without prejudice at any time.

Please Print BELOW:

______________________________________//__________//__________
Student Name (please PRINT)Math Teacher School Period

____
Student (signature) Date

Questions: Please direct any questions to Gary S. Plano, executive director, instructional services for more information. He can be reached at 373-7285.

APPENDIX G

Letter of Consent

To: Parents and Students in 9th Grade Algebra I-II and Algebra I-II CT

From: Gary Plano

Subject: Research Project

Researcher

I am a graduate student at Seton Hall University in the College of Education and Human Services. I am conducting a study this spring, which is part of my work in the Executive Doctoral Program.

Purpose of Research

The purpose of the research project is to examine the effects that the *Cognitive Tutor Algebra* program, a program used in some 9th grade algebra classes, has on student achievement and on student attitudes about math. District-directed assessments, the Achievement Levels Test and the Iowa Test of Educational Development will be used to measure achievement. An attitudes survey called the Fennema-Sherman Mathematics Attitudes Scales will be used to measure student attitudes.

Description of Procedures

In order to assist me with my project, the Fennema-Sherman Mathematics Attitudes Scales will be presented to students. Participants will be asked their general attitudes about mathematics and the degree of confidence they have around math topics. The survey takes approximately 15 minutes. It will be given once in the spring and once again at the end of the year. With regard to measuring student achievement, student scores from regularly scheduled, school district assessments--the Achievement Levels Test and the Iowa Test of Educational Development, will also be used.

Participation

This is strictly voluntary. For those who choose not to participate, there will be no penalty or loss of any kind. Student can withdraw at any time. To those students who choose not to participate, alternate classroom assignments will be provided.

Anonymity

Student data will be collected using Kent School District's student identification system which consists of numeric digits only. No student will be identified by name. No individual student data will be identified or will any student be named in the research project. Anonymity will be maintained throughout. In addition, data will only be reported by class and not by student identifiers.

Confidentiality and Security

Confidentiality is assured. As the researcher only my mentor and I will have access to the information, but at no time will anyone know or trace student answers to a given name. Materials associated with the project will be kept in the researcher's home and destroyed three (3) years after completion of the project.

Risks

There are no foreseeable risks to students concerning their answers to questions about their attitudes about math.

Benefits

There are no expected direct benefits to students who participate; however, researchers and others may have interests in how students perceive mathematics—particularly algebra.

This project has been reviewed and approved by the Seton Hall University Institutional Review Board for Human Subjects Research. The IRB believes that the research procedures adequately safeguard the subject's privacy, welfare, civil liberties, and rights. The Chairperson of the IRB may be reached through the

Office of Grants and Research Service. The telephone number of the Office is (973) 275-2974.

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Parent Permission Forms--- Please return this portion to your son/daughter's math teacher.

I have read the material above, and any questions I asked have been answered to my satisfaction. I agree to participate in this activity, realizing that my son/daughter may withdraw without prejudice at any time.

______________________________________//__________//________

Student Name (please PRINT)Math Teacher School Period

____

Parent (signature) Date

If students or parents have any questions about this research project, they should contact Gary Plano, executive director of instructional services at 373-7285.

APPENDIX G

FSMAS- Pretest

Directions: Recall how you felt right after **you finished 8th grade math last June**. Now get ready to read. The following statements contain a series of ideas about math. There are no correct answers for these statements. They have been set up in a way which permits you to indicate the extent to which you agree or disagree with the ideas expressed. Remember how you felt right after you completed 8th grade math.

Example

I like mathematics.

As you read the statement, you will know whether you agree or disagree. If you strongly agree, blacken circle **E** next to the corresponding number on your answer sheet. If you agree with some reservation or concern, and you do not fully agree, blacken circle **D**. If you disagree with the idea, indicate by blackening circle **B** or circle **A** if you strongly disagree. If you are undecided or are unsure if you can answer the question, please blacken circle **C**.

Remember, there are no "right" or "wrong" answers. The only correct responses are those that are true for you. **Whenever possible, let the things that happened to you during this past year in your algebra class help you make a choice.**

THIS INVENTORY IS BEING USED FOR RESEARCH PURPOSES AND NO ONE WILL KNOW WHAT YOUR RESPONSES ARE.

1. Generally, I have felt secure about attempting mathematics.
2. Winning a prize in mathematics would make me feel unpleasantly noticeable.
3. Math has been my worst subject.
4. I'm no good in math.
5. People would think I was weird if I got A's in math.
6. I have a lot of self-confidence when it comes to math.

7. Being regarded as smart in mathematics would be a great thing.

8. I'm not the type to do well in math.

9. It would make me happy to be recognized as an excellent student in mathematics.

10. I am sure I could do advanced work in mathematics.

11. I don't like people to think I'm smart in math.

12. I'd be happy to get top grades in mathematics.

13. Most subjects I can handle o.k., but I have a knack of messing up in math.

14. For some reason even though I study, math seems unusually hard for me.

15. It would be really great to win a prize in mathematics.

16. I don't think I could do advanced mathematics.

17. Being first in a mathematics competition would make me pleased.

18. If I had good grades in math, I would try to hide it.

19. I am sure that I can learn mathematics.

20. If I got the highest grade in math I'd prefer no one knew.

21. I can get good grades in mathematics.

22. I'd be proud to be the outstanding student in math.

23. It would make people like me less if I were a really good math student.

24. I think I could handle more difficult mathematics.

APPENDIX H

FSMAS Posttest

Directions: **React to these statements as you recall experiences from this 9th grade course**. Now get ready to read. The following statements contain a series of ideas about math. There are no correct answers for these statements. They have been set up in a way which permits you to indicate the extent to which you agree or disagree with the ideas expressed.

Example

I like mathematics.

As you read the statement, you will know whether you agree or disagree. If you strongly agree, blacken circle **E** next to the corresponding number on your answer sheet. If you agree with some reservation or concern, and you do not fully agree, blacken circle **D.** If you disagree with the idea, indicate by blackening circle **B** or circle **A** if you strongly disagree. If you are undecided or are unsure if you can answer the question, please blacken circle **C.**

Remember, there are no "right" or "wrong" answers. The only correct responses are those that are true for you. **Whenever possible, let the things that happened to you during this past year in your algebra class help you make a choice.**

THIS INVENTORY IS BEING USED FOR RESEARCH PURPOSES AND NO ONE WILL KNOW WHAT YOUR RESPONSES ARE.

1. Generally, I have felt secure about attempting mathematics.
2. Winning a prize in mathematics would make me feel unpleasantly noticeable.
3. Math has been my worst subject.
4. I'm no good in math.
5. People would think I was weird if I got A's in math.
6. I have a lot of self-confidence when it comes to math.

7. Being regarded as smart in mathematics would be a great thing.

8. I'm not the type to do well in math.

9. It would make me happy to be recognized as an excellent student in mathematics.

10. I am sure I could do advanced work in mathematics.

11. I don't like people to think I'm smart in math.

12. I'd be happy to get top grades in mathematics.

13. Most subjects I can handle o.k., but I have a knack of messing up in math.

14. For some reason even though I study, math seems unusually hard for me.

15. It would be really great to win a prize in mathematics.

16. I don't think I could do advanced mathematics.

17. Being first in a mathematics competition would make me pleased.

18. If I had good grades in math, I would try to hide it.

19. I am sure that I can learn mathematics.

20. If I got the highest grade in math I'd prefer no one knew.

21. I can get good grades in mathematics.

22. I'd be proud to be the outstanding student in math.

23. It would make people like me less if I were a really good math student.

24. I think I could handle more difficult mathematics.

APPENDIX I

Approval to Conduct Research

February 10, 2003

Gary Plano
2606 Queen Anne Ave., North
Seattle, WA 98109-1821

Dear Mr. Plano:

I have reviewed the information you provided regarding your proposed dissertation research *Effects of the Cognitive tutor algebra on student achievement and attitudes in a 9th grade algebra course.* Today we acted to approve your request to conduct research in the Kent School District in accordance with Policy and Procedures 2500. We expect all Kent School District Policies and Procedures to be followed. A copy of those will be provided for your information.

We realize that your proposal must still be approved by Seton Hall University. Any substantive changes required by your committee will need to be reviewed to ensure that they do not alter the level or type of involvement of the district that was understood from the proposal.

If you have questions, please feel free to contact me (253-373-7225).

Sincerely,

Steve Siera, Director
Research and Program Analysis

c: Mark Haddock

APPENDIX J

Approval from Seton Hall University's IRB

March 12, 2003

Gary Plano
2606 Queen Anne Ave. North
Seattle WA 98109

Dear Mr. Plano:

The Seton Hall University Institutional Review Board has reviewed the information you have submitted addressing the concerns for your proposal entitled "The Effects of the Cognitive Algebra Tutor on Student Attitudes and Achievement in a 9th Grade Algebra Course". Your research protocol is herby approved as amended through expedited review. The IRB reserves the right to recall the proposal at any time for full review.

Enclosed for your records are the signed Request for Approval form and the stamped original Consent Form. Make copies only of this stamped form.

The Institutional Review Board approval of your research is valid for one-year period from the date of this letter. During that time, any changes to the research protocol must be reviewed and approved by the IRB prior to their implementation.

According to federal regulations, continuing review of already approved research is mandated to take place at least 12 months after this initial approval. You will receive communication from the IRB Office for this several months before the anniversary date of your initial approval.

Thank you for your cooperation.

Sincerely,

Giuliana Mazzoni, Ph.D.
Associate Professor
Director, Institutional Review Board

cc: Charles Achilles, Ed.D.