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CONCEPTUAL UNDERSTANDING
IN A COMPUTER-ASSISSTED ALGEBRA 1 CLASSROOM

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CONCEPTUAL UNDAERSTANDING IN A COMPUTER-ASSISSTED ALGEBRA 1 CLASSROOM

A Dissertation APPROVED FOR THE
DEPARTMENT OF INSTRUCTIONAL LEADERSHIP AND ACADEMIC CURRICULUM

BY

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As I deposit this dissertation at the library I am reminded of a quote that my Dad used quite often … "If a task is once begun never leave it 'til its done. May the labor GREAT or small do it right or not at all!" Growing up I chose too often the "not at all" but not this time. I wish he could be here, but I know he's proud.

There are so many that have helped, supported, and encouraged me to get to this point. My committee, my friends, my fellow teachers & coaches, my family, and my God are the best. To my committee I thank you for sticking it out. We lost some along the way but as they say, "only the STRONG survive." So thank you. To my friends that helped Amy and I at times with activities for her and the kids to go to so I could write or study, I thank you. To my fellow teachers and coaches, I say to you that you can do anything you want as long as you keep your priorities straight. When in doubt, look up!

To my family, Mom you have from the start always encouraged me to do the best I can, and if I did that then I could feel good about my accomplishments. Well, I feel good. Amy you have been incredible in your own way you kept me focused when I wanted to give up, you have been a source of strength that I needed to complete this. You are Incredible and I am very lucky! As for Will, Justin, and Jemma there will be no more going to the Zoo or the Library so Dad

can write. I will now be able to participate in ALL of these activities. My family deserves a standing ovation for their support of me during this time!

I feel very good about how I managed this degree. Early on, I was told that at some point the completion of this degree would need to be number one, and that ALL other things would take second place. I am proud to say that this piece of advice was one that I proved wrong. Throughout all 6 years I kept my priorities straight and knew what and who was number one.

All I can say now is IT IS FINISHED!

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ABSTRACT

Conceptual Understanding in a Computer-Assisted Algebra 1 Classroom
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Over the last several decades, technology has had a tremendous impact on all parts of our society. In education the calculator in the 1970's, the computer in the 1980's and the World Wide Web of the 1990's have bombarded us with advances, to such a degree that state and federal leaders along with national education organizations have put pressure on our schools to implement new standards and mandates. These implementations are asking schools to increase test scores while teaching with connectedness and understanding. This seems almost impossible with our mathematics curriculum.

One solution districts are contemplating is using computer-assisted-instruction (CAI). Examining the potential for a CAI environment in the teaching, learning, and development of understanding of mathematics in an Algebra 1 classroom is the focus of this study. This study utilized a mixed methodology and focused on CAI's influence on algebra 1 students' developing conceptual understandings during a typical unit. The CAI program Cognitive Tutor has shown increases in student achievement (i.e. standardized tests) but a key issue is whether the students understand the concepts any better.

This study explored this influence on algebra 1 students utilizing the CAI program Cognitive Tutor with those in a traditional direct instruction class. The

students were tested pre and post for achievement and a subset of the sample, six from the control (direct instruction) group and six from the treatment (Cognitive Tutor) group, constructed concept maps throughout the study to be used as a measure of the conceptual understandings. The six students from the treatment group (Cognitive Tutor) went through an interview to attempt to understand what aspects of the Cognitive Tutor program they felt had the most influence on their sense making and understanding.

The analysis indicated that Cognitive Tutor, as a complete program, increases student achievement, deepens understanding and connectedness of concepts, and left them with a feeling that Cognitive Tutor had many characteristics that their best math teacher would possess. Although these analyses answered the questions of this study, future research is needed.

CHAPTER 1

Why this project?

Personal Background

Technology in school has always intrigued me. It must have been 1977 or 1978 when I was in the fifth grade. My teacher told me I would be going to a different room for one hour for reading. When I entered the room, the teacher introduced me to a machine that was to help me with my reading. This was my introduction to educational technology, at least the first that I can remember. There were other students in the class all working. I liked it, did well, made improvement, and the next year I was sad to hear that I would not have the same class. This experience wet my whistle, so-to-speak, for the use of technology in education.

My next recollection of educational technology was not as enjoyable. It was the calculator, and as students, we wanted to use the tool, but the teachers saw it differently. The teachers thought it was a form of cheating. This technology still stirs debate whether or not children learn better with calculators or if it is just a crutch (Wheatley, 1991).

It was during this time that the personal computer started to make its impact. With the advent of the internet and society's unquenchable thirst for better and faster technology, the computer went from being a novelty to a "neat" activity center to a tool for life. These experiences during my education have not only lead me to be the teacher that I am, but also have lead me to ask many of the questions that I have as a researcher, of which this study explored a few. Can technology enhance learning? That is, can educational technology influence the conceptual understandings that students develop in mathematics and not just prepare them for “the” test?

Technology’s Impact

Over the last several decades, technology has had a tremendous impact on all parts of our society, especially education. The calculator in the 1970's, the computer in the 1980's and the World Wide Web of the 1990’s have bombarded us with advances to such a degree that the way we think of education, and more specifically mathematics education, is from these new perspectives. Since the inception of the Internet and its explosive growth, technology has continued to meet and surpass societal demands. This explosive growth of technology has resulted in referring to this time in history as the “information age.” With society’s interest and emphasis on technology, it is no wonder that computers have influenced almost every aspect of our lives from entertainment, to the workplace, and now, to education. In order to prepare students to meet the challenges of this new age, our schools are withstanding continuing stress to make “good” decisions regarding the direction of education and the use of technology.

In light of the current technological and information age, there is immense pressure for education to “produce” graduates that are technologically, and mathematically literate. Federal mandates like "No Child Left Behind" are adding tension by legislating accountability through standardized testing, and instructional reforms that are scientifically "proven" to improve student achievement in all subjects more specifically mathematics (NCLB, 2001). Calls for educational reform from professional organizations, such as the International Society for Technology in Education (ISTE) and the National Council of Teachers of Mathematics (NCTM) are increasing this stress by advocating the integration and effective use of technology all the way down to the state and local district levels, and straight into the mathematics classrooms.

Calls for Change:
Incorporating Technologies in the Teaching of Mathematics

According to the NCTM (2000), "technology is an essential tool for teaching and learning mathematics effectively. Technology extends the mathematics effectively taught, and enhances student learning" (p. 24). The NCTM emphasizes using technology as a tool to model, graphically represent, and analyze data as an aid in building new knowledge, so students will generalize, recognize connections, and represent ideas and thoughts differently (NCTM, 2000). NCTM's Principles and Standards of School Mathematics (2000) explain, "when technological tools are available, students can focus on decision making, reflection, reasoning, and problem solving" (p. 24). The envisioned classroom environment provides every student access to technology so his or her mathematics learning can deepen (NCTM, 2000). The guidance of skillful teachers in the effective use of new technologies in the teaching of mathematics enhances the students' learning opportunities (NCTM, 2000). Based on these recommendations, individual states and local districts have made concentrated attempts to incorporate technology into an already overburdened mathematics curriculum. With the move of western countries from an industrial age to an information age, many, agencies, educators, policy makers, and education stakeholders are currently reviewing what mathematics our students really need to know and what changes need to take place for our students to be equipped for the twenty-first century as qualified potential employees (NCTM, 2000; ISTE, 2000).

Within the context of these reform efforts for incorporating technology in the teaching of mathematics are the increased demands by the No Child Left Behind Act (NCLB) to use scientifically proven methods of instruction that directly affect student achievement. NCLB (2001) calls for increased accountability of student performance; research based reforms, heightened parent empowerment, and improved flexibility in our educational system to increase student learning, and therefore student achievement. NCLB and other reforms have focused on the need for instruction to change and promote what NCTM calls "meaningful learning," learning with understanding and connectedness (NCTM, 1989, 2000). For the purposes of this study, meaningful learning is defined in terms of student understanding and the connectedness of mathematical concepts.

The increasing of these connections and deepening conceptual understanding is a focus of this study. The call for meaningful learning alerts those of us in education to an apparent lack of connectedness in our "mile wide and inch deep curriculum" (TIMSS, 1999). Since the Third International Mathematics and Science Study (TIMSS) reported that the U.S. performed so poorly on the international level, mathematics education in the U.S. has been under the watchful eye of almost every policy maker, legislator, educator, and business leader. It is clear that mathematics education in the U.S. is in need of reform (NCLB, 2001) by building a deeper conceptual understanding of mathematics.

According to NCTM (2001), research has solidly established the importance of conceptual understanding in becoming proficient in a subject. Hiebert and Carpenter (1992) and Eisenhart et al. (1993) have explored the use of the term conceptual knowledge. Conceptual knowledge plays a very important role in promoting understanding in any subject, especially mathematics. Conceptual knowledge is knowledge that is rich in relationships, which advance connectedness and understanding (Eisenhart et al., 1993; Hiebert & Carpenter, 1992; Royer, Cisero, & Carlo, 1993). When students understand math, they are able to use their knowledge in a flexible way. They combine factual, procedural, and conceptual knowledge in powerful ways, thus making mathematics meaningful. Conceptual understanding enables students to deal with rich problems and settings that they have not encountered before in very deliberate and powerful ways (NCTM, 2000). Conceptual knowledge as Hiebert and Carpenter (1992) have described is conceptual understanding. Conceptual understanding should be the priority of mathematics learning and teaching (NCTM, 2000), which guides us to formulate and test the principles of mathematics. When students exercise their own knowledge within a given situation, they are led down a road of possibility, a possibility of constructing new knowledge. This is an example of meaning making, meaningful learning or understanding (Hiebert & Carpenter, 1992; Pintrich, Marx, & Boyle, 1993).

The dilemma that we face is implementing these calls for reform into an already overloaded curriculum, while continuing to deepen our children's understandings. One solution that districts are contemplating is using computer-assisted-instruction (CAI). CAI is one way in which educators are attempting to bring together procedural and conceptual knowledge to deepen our students' understandings in mathematics. Examining the potential for a computer-assisted-instruction environment in the teaching, learning, and development of understanding in mathematics in an Algebra 1 classroom is the focus of this study.

CAI and Cognitive Tutor

Computer-assisted-instruction (CAI) is being examined in several different ways. CAI is an interactive instructional method that uses a computer to present material, track learning, and direct the user to additional material, which meets the student's needs (Bucholtz, 1998). CAI also uses the Internet for instruction by utilizing web pages, web bulletin boards, listservs, newsgroups, video, real audio, and graphics (Bucholtz, 1998; Fourie, 1999). The pressures to have our students achieve and understand their mathematics in a deeper way has been a driving force for the development of CAI technology.

In the pursuit of this higher achievement, CAI curricula tend to use alternate forms of assessment including performance tasks, long-term projects, student portfolios, and journal writing (Koedinger et. al., 1997). Teachers are more likely to be facilitators and provide more one-on-one instruction with individual students when CAI provides the instruction and monitoring of student progress. This experience, for many teachers, opens their eyes "to see new aspects of student thinking and feel the advantages of greater student-centered learning-by-doing" (Koedinger & MacLaren, 1997).

Traditionally, CAI has been a little more than "electronic worksheets," CAI was linear in nature in that students would work through material in a specific set sequence. However, with the advent of web-based instruction technologies, CAI has moved to a nonlinear level (Lawson, 1999) with intelligent computer-assisted-instruction (ICAI). ICAI is new software that makes use of artificial intelligence and actually adapts to the individual needs of each student (Moursund, 1998; Schofield et. al., 1990). Cognitive Tutor, developed by Carnegie Learning Incorporated in conjunction with Carnegie Melon University, is a software package that utilizes this "new" intelligent technology for CAI.

For almost 20 years, Carnegie Learning and Carnegie Mellon University have conducted research into student learning, specifically in mathematics. Thus Cognitive Tutor has been adopted in many school districts across the United States to replace or supplement traditional algebra instruction. In addition, many of the schools that use Cognitive Tutor have carried out their own research to ascertain the effectiveness of the Cognitive Tutor solution. Most have determined from their findings that Cognitive Tutor shows benefits on standardized tests as compared with traditionally taught classes (Koedinger et. al., 1997). Cognitive Tutor creates individualized student cognitive models and then provides "just-in-time" instructional intervention. Cognitive Tutor's complete curriculum not only utilizes the computer to teach and introduce new mathematics concepts, but also has a classroom component that complements this instruction. A cooperative learning environment where students work in groups on rich, complex, "real-world" problems is where the application of the skills learned at the computer become real (Carnegie, 2002).

John Dewey argued over 100 years ago for changes that would move schools away from authoritarian teacher-centered classrooms, to environments in which learning happens through experimentation, practice, and exposure to the real world (Dewey, 1990). Over this same period, mathematics teaching and instruction has continued with little change. In our current "information age," Cognitive Tutor has the potential to provide alternatives to teacher centered instruction. The United States government has recently shown its confidence in Cognitive Tutors' potential in improving student achievement in Algebra 1 by naming it one of five national exemplary educational programs. In naming Cognitive Tutor a national exemplary educational program, it was one of the programs to take part in the scheduled U.S. Department of Education's Technology Study during the 2004-2005 school year. With the recommendations from national education organizations and the added pressures of legislative mandates it can be readily seen that technology will continue to hold a secure place in education. Our job as teachers then is to make sure its use is best for our students. That is to say, technology should deepen their understandings and increase their connections to previous knowledge and not simply function as remediation for performance or as practice tools for standardized tests. While the relationship between student achievement and student learning is not equivocal, they are related. The question is, "Can Cognitive Tutor have a positive influence on conceptual understanding also?"

In order to understand student thinking in the current study, concept maps have been used to identify the relationships between concepts or ideas as a "snapshot" of a student's conceptual understanding at that time (White & Gunstone, 1992). More recently, concept maps have been utilized more and more in the teaching and learning of mathematics (Bolte, 1999) to catch a glimpse of students developing webs of understanding. The intent of the study presented here was to track the ongoing conceptual understandings as students experience mathematical problem solving in an algebra 1 classroom that utilizes the computer-assisted-instruction environment, Cognitive Tutor.

It is worth noting that in the study presented here that this study was limited to the CAI program Cognitive Tutor. Therefore, any implications presented here must be viewed in light of this fact. An additional limitation would be the utilization of concept maps as a tool to attempt to understand the conceptual understandings of the observed students. The use of concept maps is the best tool used in research today to catch this glimpse of students meaning making and understandings. The aim of this study is not to diminish or reduce the complexity of the human mind but to gain some insight to help students reach their potential. The guiding questions of the study were:

1.) What influences does the Cognitive Tutor CAI program have on the achievement and conceptual understandings of algebra 1 students?

2.) What factors influenced any observed gains?

3.) What factors or aspects of Cognitive Tutor do students consider having the most influence in their understandings and sense making?

Chapter 2 will look at the literature pertaining to the questions of this study. We will explore what existing literature says about Computer-Aided Instruction programs, the Cognitive Tutor program, conceptual understandings, and concept maps in the algebra 1 classroom.

Significance of the Study

The goal and significance of this study was to examine the influences to the conceptual understanding of algebra 1 students in a CAI environment, Cognitive Tutor as compared with those in a traditional direct instruction environment. With the movement of our society to more and more technology based and reliant it was only time before this movement would journey into our schools. At the same time mathematics education in the U.S. is in a trend of teaching for conceptual understanding and not just for achievement on national and international standardized tests

This study contributes to the body of academic knowledge by describing if the CAI program Cognitive Tutor had an impact on student conceptual understanding and if so what aspects of the program had the most influence from the student's perspective. Furthermore, this study provides extensions and possible future research topics that were illuminated during this study but were not its focus.

Limitations of the Study

It is worth noting that the study presented here was limited to the CAI program Cognitive Tutor. Therefore, any implications presented must be viewed in light of this fact. In additional, the utilization of concept maps as a tool to understand the conceptual understandings of the observed students is also a limitation since concept maps only provide a glimpse of students meaning making and understandings. The aim of this study is not to diminish or reduce the complexity of the human mind but to gain some insight to help students reach their potential. Additional limitations include:

1. This study took place only in a southwestern United States suburban high school within a city that consisted of a majority of adults having college degrees.
2. The Pre and Post Tests were teacher made and used to gage achievement during the study.
3. The sample was 120 students, 90 enrolled in the Cognitive Tutor algebra 1 and 30 in the traditional direct instruction classes.
4. Six algebra 1 students from the traditional direct instruction class and six from the Cognitive Tutor CAI classes participated in the construction of the concept maps and these were used observe the changes in conceptual understanding each environment had on the students.
5. The six algebra 1 Cognitive Tutor CAI students who constructed the concept maps were interviewed to determine what aspects of the Cognitive Tutor Program had the most influence.

Definitions and Terms

Achievement in mathematics is often used as a sign of “how much” mathematics someone knows, usually by the use of a standardized test or teacher made test. In this study a teacher made test was made and used to measure achievement during the study. (See appendix J & K)

Concept maps can communicate a student's organization of ideas and relationships and connectedness among other ideas and knowledge. (Novak, 1998; Wallace & Mintzes, 1990) Concept maps provide a clearer depiction of the concepts and propositions a person holds. (Novak & Gowin, 1984)

Conceptual understanding is knowledge rich in relationship to present and past knowledge and experiences. (Hiebert & Carpenter, 1992) Hiebert & Carpenter (1992) and White & Gustone (1992) agree that for newly acquired knowledge to be useful connections must be made to previous knowledge and experiences. NCTM equates conceptual understanding and Meaningful learning as learning with understanding and connectedness. (NCTM, 1989, 2000)

Meaningful learning, according to Novak (1998), is learning where the learner integrates new concepts into previously acquired and constructed knowledge.

CHAPTER 2

What's being said?

Literature Review

Computer technology has influenced almost every aspect of society from transportation to healthcare, and now effective technologies are beginning to reshape education and the mathematics classroom. The National Council of Teachers of Mathematics (NCTM) was the first professional organization to create national standards for the appropriate uses of technology in a content area (NCTM, 2000). NCTM's standards set a research base for the essential use of technology in the effective teaching of mathematics (pg. 24) as well as for teaching of mathematics for conceptual understanding to have students attain proficiency. The call for this kind of technology use and teaching of mathematics helped to focus this study.

The purpose of this study was to track student's ongoing conceptual understandings as they experience mathematical problem solving utilizing the Cognitive Tutor computer-assisted-instruction program.

The guiding questions of the study were as follows:

1.) What influences does the Cognitive Tutor CAI program have on the achievement and conceptual understandings of algebra 1 students?

2.) What factors influenced any observed gains?

3.) What factors or aspects of Cognitive Tutor do students consider having the most influence in their understandings and sense making?

CAI and Cognitive Tutor

With a majority of schools in the United States now equipped with computer technology for student use, the effectiveness of computer-assisted-instruction programs for student learning is an issue of growing concern. State and local districts seek evidence that computer use enhances learning. Most school districts and their stakeholders equate "enhanced learning" with higher standardized test scores. Yet, the relationship between student achievement and student learning is not equivocal, because many times students can have good test taking strategies and score higher than their actual understanding of the concepts. Clearly, achievement and learning are related, and thus our nations guiding organizations are looking more intently on conceptual understanding (NCTM, 2000).

As early as the Kulik, Kulik, and Bangert-Drowns (1985) study, there has been an obvious need to define the many different terms for the use of computers in instruction. Computer-assisted instruction (CAI), computer-based education (CBE), computer-based instruction (CBI), computer-enriched instruction (CEI), and computer-managed instruction (CMI) can easily become confused, and at times are interchanged despite differences in meaning. CAI most often refers to drill-and-practice, tutorial, or simulation activities offered either by themselves or as supplements to traditional, teacher centered/direct instruction. Cognitive Tutor, a computer-assisted-instructional (CAI) tool and the subject of this study, falls into this category (Kulik, J.A., 1983; Kulik, J.A., & Kulik, C.C., 1987).

Cognitive tutor is a software program that introduces, reviews, and assesses different topics/concepts of algebra 1. The program records, charts, and anticipates student progress as they work though the programs' curriculum. When the program senses a problem area, it evaluates the appropriate next step for the student. It may offer help, by offering a similar problem situation, or reminding the student of an earlier successful problem. This help shows the students how their approach was different.

Early on, CAI has shown effectiveness as a supplement to traditional instruction. Jamison, Suppes, and Wells (1974) reviewed a wide range of CAI research and concluded that CAI programs in general are effective as a supplement to regular instruction. In 1975, Edwards, Norton, Taylor, Weiss, and Dusseldorp found that CAI as a supplement to regular instruction was uniformly effective, and the substitution of CAI for traditional instruction showed no significant difference. The high cost of computers and the lack of evidence as to the effectiveness of CAI as a replacement to traditional instruction stifled the use in public schools early on (Bracey, 1987; Christmann & Badgett, 1999; Kulik, J. A., Kulik, C. C., Bangert-Drowns, R. L., 1985; McDermott & Watkins, 1983). The rapid growth in technology throughout the 1990's making technology cheaper, faster, and more effective suggests that the impact of technology in education has changed (Allen, 2001), and CAI use may be practical and effective.

CAI can lead to more positive student attitudes than the use of direct instruction. This general finding has emerged from studies on the effects of CAI on: (a) attitudes toward computers and the use of computers in education (Bracey, 1987; Ehman & Glen, 1987; Kulik, J., 2003; Latham, 1999), (b) course content/subject matter (Bracey, 1987; Ehman & Glen, 1987) Quality of instruction (Bracey, 1987; Ehman & Glen, 1987, Latham, 1999), (c) attitudes toward school (Bracey, 1987; Ehman & Glen, 1987), (d) better attendance (Bracey, 1987; Ehman & Glen, 1987; McCoy, 1996) and (e) higher rates of time-on-task than traditionally instructed students (Bracey,.1987; Ehman & Glen, 1987; Fletcher, 1990). Most comparative studies have shown CAI to be beneficial for younger students rather than older ones and with lower-achieving students rather than higher-achieving students (Kulik, J., 2003; McCoy 1996). Researchers have also made note that CAI benefits the low achieving and economically disadvantaged (Kumar & Wilson, 2000; Latham, 1999; McCoy 1996).

An evaluation conducted on the Algebra Tutor, an early version of Cognitive Tutor, (1987-1988) showed no differences on achievement measures between experimental classes (which had access to the tutor) and the control groups (which did not). After significant changes in the program itself, as well as advances in technology and increasing students' technological sophistication, the potential of the next generation of Cognitive Tutor showed promise and a need for further research (Koedinger et al., 1997).

Carnegie Learning's website, has reviewed several studies including the Houston Independent School District and Moore Public Schools studies, which summarized the characteristics of the general findings of Carnegie Learning's sited research. The Houston Independent School District study showed that after one year of implementation, pass rates for the Texas End Of Course (EOC) exams soared to 54% in Reagan High School's at risk algebra 1 class, up from 19% the previous year (Morgan & Ritter, 2002). In Moore, Oklahoma, students who had used Cognitive Tutor showed a significant advantage on all dependent measures, including the Algebra End-of-Course assessment, course grades, and measures of student attitudes towards mathematics. For the Moore Oklahoma students, the Algebra End-of-Course Assessment consisted of 25 multiple-choice and 15 constructed-response questions, with each type of question accounting for 50% of the student's score. Although the Moore students' scores were slightly below the national mean (average), follow up surveys showed that both teachers and students were enthusiastic about the Cognitive Tutor course (Morgan & Ritter, 2002). When asked whether the Cognitive Tutor algebra 1 course was more, less or equally effective compared to other math courses they had taken, 63% of students indicated that they felt the course was more effective. Only 13% said it was less effective. Seven of the eight Cognitive Tutor teachers returned a questionnaire distributed at the end of the school year, and all seven responded, “Yes” when asked if they would recommend the Cognitive Tutor to others (Morgan & Ritter, 2002).

Carnegie Learning (2002) claims that students using Cognitive Tutor: perform 30% better on questions from the TIMSS assessment; 85% better on complex mathematical problem-solving and thinking; and have a 70% greater likelihood of completing subsequent geometry and algebra 2 courses. Cognitive Tutor students display an advantage of 15-25% on the SAT and Iowa Algebra Aptitude Test, and state end of instruction exams (Koedinger et al., 1997).

“Cognitive Tutor frees teachers to observe individual student work more often, and allows them to reflect on their instructional practices in the context of one-to-one interaction with students” (Koedinger et al., 1997, pg. 31). Student feedback during these interactions should provide teachers with immediate and detailed feedback on the effectiveness of their practices. This feedback could then be used by the teachers to adjust and improve their instructional practices, and become artists of their profession, which can only occur with reflection on one’s own practice or craft (Henderson, 2001). “Teachers working in the computer lab have more time to observe student performance on thought revealing problems and observe the learn-by-doing curriculum in action. In this way, Cognitive Tutor can carry research-based practices into the classroom and serve as a change agent for the profession," according to Carnegie Learning (2002).

Computer-assisted-instruction (CAI) is an interactive instructional method that uses a computer to present material, track learning, and direct the user to additional material, which meets the student's needs. Traditionally, CAI was linear in nature in that students would work through material in a specific set sequence. With the advent of web-based instruction technologies, however CAI has moved to a nonlinear level (Lawson, 1999) with intelligent computer-assisted-instruction (ICAI). ICAI is new software that makes use of artificial intelligence and actually adapts to the individual needs of each student (Moursund, 1998; Schofield et. al., 1990). Several ICAI applications are currently being developed including an intelligent multimedia tutoring system that teaches the use of hospital emergency room equipment, one that teaches students how to create broadcast news reports (Moursund, 1998; Schofield et. al., 1990,) and Cognitive Tutor in the mathematics classroom.

The federal government named Cognitive Tutors one of five national exemplary educational programs. With this honor, Cognitive Tutor was included as one of the programs to take part in the scheduled U.S. Department of Education's technology study during the school year 2004-2005. Technology should deepen student understandings, increase the connections to previous knowledge, and not simply function as an achievement boost for standardized tests. Although student achievement and student learning are not equivocal, they are related. Which raises the question,"Could Cognitive Tutor have a positive influence on conceptual understanding?"

Conceptual Understanding

The review of literature shows that CAI and Cognitive Tutor can help students to improve achievement on standardized tests. While this does not equate with meaningful learning or understanding, it is related. The literature also shows that leading national mathematics organizations are calling for mathematics teachers to teach in such a way that students develop deeper conceptual understandings. Conceptual understanding is "meaningful learning," learning with understanding and connectedness (NCTM, 1989, 2000).

These calls for change from NCTM and other learned societies and legislative mandates call teachers to change instructional practices and to help students develop deeper conceptual understanding (NCTM, 2000; ISTE, 2000; NCLB, 2001). According to Wheatley and Reynolds (1999) our should not be to assign a certain number of problems each night but rather to learn with understanding and deepen it with every activity. To explore effective ways to change instructional practices it would be good to see what practices are like in general now. "Traditional" teacher-directed instruction has its roots in behaviorism. Behaviorism, a theory of animal and human behavior asserting that actions are responses to some stimulus, attributes learning as a reaction to a teacher initiated event or action that in turn stimulates the student to new understanding. Behaviorist teaching is essentially a matter of arranging reinforcement to produce and maintain scripted behaviors (Houghton, 1995). In contrast, Piaget, a cognitive epistemologist, described three cyclic phases for conceptual change including exploration, term introduction, and concept application (Duit & Confrey, 1996). In this approach, students first explore the concept and begin to construct the new concept in the given situation. Second, they are introduced to the term that is related as the name of the constructed concept. And third, students apply the new concept to new situations that in turn expand and deepen their understanding. This approach is general and has different sub-phases that can be constructed to promote the understanding of a particular concept. A more contemporary learning paradigm is Constructivism. The theory holds that the learner, rather than the teacher, develops or constructs knowledge and that opportunities created for construction are more important than instruction that originates from the teacher (McCoy, 1996; Piaget, 1985). McCoy (1996) makes the claim that CAI is a constructivist environment where students are free to construct their own meaning/knowledge. When students are learning in an environment with this freedom, meaningful learning is encouraged through connections and deeper understanding (Dewey, 1990; Piaget, 1985; von Glassersfeld, 1995).

Concept Maps

Ways of probing the conceptual understanding of learning include concept mapping, prediction-observation-explanation activities, interviews about instances, events and concepts, drawings, fortune lines, relational diagrams, word associations and question production (White & Gustone, 1992). Among these tools, concept maps are useful in probing the understanding of mathematics learning and have been used to do just that (Williams, 1998). Since students' informal writing about mathematical content and concepts is also evidence of mathematical understanding, concept maps provide opportunities for this avenue of expression. It is necessary, at this point to explain each of these tools and methods of probing for understanding in relation to mathematics learning.

The purpose of a concept maps is to assist in showing how an individual identifies the relationships between things, persons or ideas (White & Gunstone, 1992). It has been widely used in science teaching and research (Novak & Gowin, 1984; Wallace, J. D., & Mintzes, J. J., 1990; Wandersee, J. H., 1990). Recently, it has been adapted for use in mathematics teaching and specifically for learning the concepts of calculus and geometry (Bolte, 1999). Concept maps can also be used to assess the understanding of number systems to assess the understanding of the relationships between different types of geometric figures and to identify the understanding of the relationship among different arithmetic concepts like percentage, ratio, fraction and decimal (Novak & Gowin, 1984).

Internal representations of knowledge are being understood as to resemble webs or networks of ideas and are organized and structured as students process information and make meaning (Hiebert & Carpenter, 1992; Hiebert & Lefevre, 1986; Pintrich, Marx, & Boyle, 1993; Royer, Cisero, & Carlo, 1993). The more connections that exist among facts, ideas, and procedures, the better the understanding (Hiebert & Carpenter, 1992; Hiebert & Lefevre, 1986). In discussion of ecosystems and community, Capra (1996, pg. 303) says, "the more complex the network is, the more complex its web of connections, the more resilient it will be." This resiliency is the deeper stronger understanding that Hiebert & Carpenter (1992) and Hiebert & Lefevre (1986) wrote about. Although Capra was not specifically addressing about analyzing concept maps, he was talking of understanding and sense making within a system. Concept maps are one way to attempt to represent the complex webs of connections that students display when constructing them.

Concept maps are a method of looking at an organization or a structure of an individual's knowledge and understanding within a particular domain and show the fluency and efficiency with which the knowledge can be used by the student (Novak & Gowin, 1984). The effective use of concept maps can shed light into otherwise non-visible areas in teaching and learning. The rationale for the use of concept maps in this study was to catch a glimpse of the student's understanding in algebra 1 and to maximize involvement of the participants and to minimize the researcher's influence. The use of concept maps allows students free expression of their connections and their understandings through writing and drawing during the construction and editing phases of concept mapping. This is not to say that a concept map is a clear depiction of a students' conceptual understandings but rather a clearer one.

"Mathematical knowledge and structure do not always lend themselves to simple categorizations, but they can be depicted well by concept maps" (Williams, 1998, pg. 414). The construction of a concept map can be the first challenge in introducing concept maps into the classroom. The ways of constructing and using concept maps varies widely and participants can draw the maps, or the researchers may construct the map from participant directives (Novak & Gowin, 1984). Novak and Gowin (1984), who invented the concept map, suggest that maps be hierarchical. By hierarchal, Novak and Gowin (1984) suggest a prioritization of the terms and ideas used to construct the concept map, starting from the most important and moving to the least important and showing this priority throughout the map. Other researchers have participants construct "spider maps" (Harnisch, et. al., 1994). These are maps with a general concept in the center and with links coming out much like a spider web or the spokes of a wheel. In drawing and labeling the linking lines in both the hierarchal and spider type maps, the participants explicitly state the relationships they saw regarding the concepts being studied.

When comparing concept maps with interviews concerning students' understanding of relationships between concepts and with the academic progression of students in a remedial mathematics course, Laturno (1994) found that concept maps seemed to be valid research tools. Park (1993) found a strong correlation between concept-map scores and post-achievement test scores in a study of a college computer lab calculus course. Data from concept maps can be reinforced, illuminated and strengthened by clarifying interviews of study participants (Williams, 1998). This is the approach taken in this study to illuminate and clarify the unfolding influences on conceptual understandings of our participants while utilizing the Cognitive Tutor program.

Most researchers using concept maps design a scoring scheme to assign a numerical value to each map. The categories used for scoring often include valid propositions, levels of hierarchy, and cross-links. They occasionally include examples. The maps drawn by the participants in this study proved to be widely divergent and did not lend themselves to a numerical scoring scheme at first. Therefore an expert map, like that used in Williams' (1998) study, was made for scoring purposes. This map was constructed by the instructing teacher to serve as "the expert" map. This map was then used as a comparison to the maps constructed by the participants which contained the polynomial and algebra 1 concepts in ovals or boxes with the words denoting relationships among concepts on the lines linking them.

This study explored the influences on conceptual understandings of mathematics learned by utilizing a CAI program Cognitive Tutor. Concept maps were used as a tool to examine the conceptual understanding unfolding as students studied algebra 1 via CAI was a benefit to the study. With that, the degree to which concept maps describe a person's actual mental representation is, of course, impossible to know, but does give us a "best view" of the students' developing conceptual understandings. It is worth noting that when conducting educational research, we must keep in mind, that not all students learn at the same pace nor adapt and learn with the same traditional approach (Jamison, Suppes, & Wells, 1974). Nevertheless, Cognitive Tutor appears to be a tool that will enhance student achievement based on Carnegie Learning data as well as other researchers' studies (Carnegie Learning, 2002; Koedinger et. al., 1997; Morgan & Ritter, 1997). We as educators and researchers owe it to our students to investigate Cognitive Tutor more thoroughly to see under which conditions and environments it benefits a deeper conceptual understanding.

CHAPTER 3

How was this explored?

Research Methodology

Over the past 20 years, a growing number of researchers have sought to explain student's mathematical understandings in a context of teaching or instruction. They have also tried to build accounts of how students learn specific mathematical concepts. NCTM has promoted change in the U.S. mathematics curriculum for years in hopes of raising standardized test scores and thus developing deeper understandings in our students (NCTM, 2000). However, the U.S. has not performed at an acceptable level when compared internationally (TIMSS, 1999), thus providing an opportunity for those concerned to ask, "How do we know what our students know?" and "What can we do to enhance student learning?"

This study examined the use of a computer-assisted-instruction program (CAI), Cognitive Tutor, in an algebra 1 classroom at a high school in the southwestern United States. The school is in a suburban district located just outside a large metropolitan area of more than one million people. The high school is one of three high schools in the district, recognized as a school that motivates teachers to develop and maintain classrooms that encourage the use of technology. The use of technology at this school is encouraged and supported by site and district administrations. This support is evident through the ongoing professional development and planned software/hardware updates that make teaching and learning a priority. After discussions with the classroom teacher as well as administrators at the site and district levels, this study initially attempted to answer these research questions:

1.) What influences does the Cognitive Tutor CAI program have on the achievement and conceptual understandings of algebra 1 students?

2.) What factors influenced any observed gains?

3.) What factors or aspects of Cognitive Tutor do students consider having the most influence in their understandings and sense making?

Research Method(s) Employed

In examining the research questions for this study, it was determined that a Mixed Method research methodology would be utilized. A mixed method research design was selected to build on the strengths of both quantitative and qualitative data as well as to complete the picture of the research problem studied (Creswell, 2002). The study examined a high school in the southwestern United States, which employed a computer-assisted-instruction program (CAI), Cognitive Tutor to facilitate algebra 1 classes.

A mixed method research methodology allowed for the measurement of the students' unfolding mathematical understandings in the Cognitive Tutor environment (quantitative) by the use of concept maps, and the illumination of which aspects of the program the students felt were most influential (qualitative).

Tashakkori and Teddlie (1998) described this method as an exploratory study that starts with quantitative data and then illuminated with aspects of qualitative data that develops a clearer picture of the results. Creswell refers to this methodology as sequential mixed method, with quantitative data first and the qualitative influence second (Creswell, 2003). Tashakkori & Teddlie (1998) and Creswell (2003) may differ on the name, but they agree on the benefits, in certain studies where the analyzing of quantitative as well as qualitative data is present.

Tashakkori and Teddlie (1998) and Creswell (2003) describe the quantitative portion of the mixed method approaches as being experimental, but for this study, we implemented a quasi-experimental approach since random assignment was not possible. Quasi-experimental studies involve manipulating one or more (independent) variables to measure the impact on a dependent variable, very similar to the true experimental study. Since assignment to the classes was done prior to the study, a true experimental design could not be utilized. The independent variable was the instruction (either direct instruction or the Cognitive Tutor Program) and the dependent variable was student understanding as measured by concept maps produced throughout the study.

This study utilized the nonequivalent group, pretest-posttest design for the quantitative portion of the study. In the beginning, the two groups were pre-tested to see if there was a statistically significant mean difference at the start of the study. In fact, the mean difference between the groups was not statistically significant on the pretest and therefore for the study the groups are essentially equal. Some problems still might result from control group accidental exposure to the treatment as one group may be more motivated than the other group. In this, study these possible problems were addressed in that the control group and treatment group were in different classes, and therefore treatment could not be accidentally exposed. The motivation of students was controlled by using the same teacher for both groups (Cook & Campbell, 1979).

Study Parameters

The study took place at a suburban high school in the southwestern United States in a high school that provides a challenging and comprehensive curriculum that prepares students for future opportunities. The graduation rate of this high school is 96.1%, the college bound rate is 72.4% and it has a college graduation rate of 47.3% (Edmond Public Schools, 2004). The city in which the school is located has a population of about 100,000 and is composed of a majority of families with parents who are college graduates or with professional or semi-professional occupations (53.4%) (Edmond Public Schools, 2004). The ethnic makeup of the school population consists of 13.8 percent African American, 4.4 percent Native American, 2.4 percent Hispanic American, 3.3 percent Asian American, and 76.1 percent Caucasian (Edmond Public Schools, 2004). Believing that the tools of technology used effectively and efficiently, are the essential skills for every person, this district's mission is to provide the resources to empower all students to succeed in a changing society (Edmond Public Schools, 2004).

The teacher assigned to the selected classes is a traditional public school mathematics teacher by his own admittance. He personally defined his instructional approach or technique as teacher-centered, teacher-directed, a "follow my steps and you will get the right answer" approach to teaching. He also indicated that the textbook is the "curriculum." He has taught and coached for 21 years; and at times during his career, he indicated that he taught to coach. Recently after reflecting on his teaching, he has begun to question some of his teaching practices. He relates this directly to his coaching experience stating, "When athletes start to understand the game, they play/perform better." He is now looking to see how he can generate this same outcome from his mathematics students.

Procedures

The initial contact with the school was to gain support and approval for the study. Contact with the building principal and district superintendent initially was handled through email. Individual meetings were then set up to give these administrators the planned procedure and purposes of the study. Both were supportive in light of the vast amount of information and data about the CAI program. The research was appreciated as a way in which the data could influence future decisions for the district and its students. The principal and the teacher both expressed their support and excitement regarding the potential for improvement of their program based on the literature and previous research shared during the meetings.

The next step was to secure district administrative approval. The superintendent wrote a letter of approval for the study (See Appendix A), which stated that the district was in full support of the research project, pending approval of IRB (See Appendix B).

After securing permission from the district, the study began with the creation of the survey. The survey implemented was to see which students were willing to participate and would be a source of data for the study. A panel of experts composed of the principal, teacher and principle investigators examined the survey for clarity. As the principal investigator, I requested feedback on the survey's content validity, unclear items, and other suggestions the experts had to improve the overall format of the survey. Once received, the experts reviewed the suggestions for the survey again, and then produced the final version of the survey (See Appendix F).

The distribution of the finalized survey, approximately 120 in all, commenced. The survey distribution occurred for recruitment purposes. Only one teacher at the school taught the three cognitive tutor algebra 1 classes. He also had one class of direct instruction algebra 1. Therefore, the classes chosen were these four. Prior to the distribution of the survey, the teacher of the classes stressed the importance of the survey and encouraged the students to answer the surveys honestly and openly. The rate of return on the surveys was 73.3%, or 88 out of 120 surveys were returned.

After the survey was completed, I randomly selected a pool of eighteen students (ten from the CAI classes and eight from the direct-instruction class) that responded that they would like to participate in the study. An interview/informative meeting was held with the eighteen randomly selected students. After this meeting, several students indicated that they were not willing-to-participate. This left six participants each from the control and experimental groups. The six participants that came from within the Cognitive Tutor classes and had regular attendance, and six regularly attended the direct instruction class. The selected participants represented genders (5 female and 7 males), various ethnic groups (9 Caucasian, 2 African-American, and 1 Hispanic), and varied in mathematical ability. The two groups of informants received a form to assent to participate in the study. Parents and guardians were also asked to give consent as these participants were all under the age of eighteen. (See Appendix B, IRB Approval).

All twelve students attended an instructional session, led by the principle researcher on concept maps, during which examples of concept maps were shown. Each map had concepts contained in ovals and linking words on the lines connecting the concepts. The examples included hierarchical maps, web or spider maps, and nonhierarchical maps. As instructed, the students could draw their maps however they wished, based on the examples provided in the instructional session. Each student then drew a concept map based on a list of terms related to algebra 1 and polynomials. The students added any other related terms to the provided list and fashioned them into their concept map. All twelve completed the task in under 90 minutes.

Observations of the classroom sessions as well as the computer lab sessions were made at least once per week for the course of the study. During the observations, the principal investigator monitored the discussions, questions, and interactions of the students. Supplementing the field notes taken during each session were video and/or audio recordings of each session.

Each of the CAI informants met each week to explore their understandings and feelings of Cognitive Tutor's impact more closely in an informal semi-structured focus group/interview setting. The recordings of these meetings were a critical part of the data set for this study. The interviews, along with the observation field notes and the data collected from various tasks, provided explanations, interpretations, and patterns to the organization and understandings of the students.

Pre-testing of all 4 classes and all 12 participants took place and each participant constructed their first concept map. At the conclusion of the study, which lasted approximately 10 weeks, each participant took the post-test and constructed a final concept map. The pre and posttests as well as the concept maps were graded for accuracy. The concept maps were graded by comparing them to the "expert" map (see Appendix H) created by the teacher of the course who for this study is the expert on what a typical algebra 1 student should know (Williams, 1998).

Credibility and Trustworthiness.

Triangulation of different the data sources adds credibility to the mixed methodology. The utilization of multiple data sources to triangulate the evaluations of the students understanding throughout the unit adds to the study's trustworthiness. These different data sources included pretest, posttest, observations, interviews, and concept maps.

Applicability, generalizability, or external validity in quantative research has its counterpart, transferability, in qualitative research. All have at their base relevance to different and/or larger contexts. In quantative research, researchers seek out relevance and in qualitative research; the researcher's role is not to determine relevance but to study the context of interest (Campbell, D. & Stanley, J., 1963; Lincoln, Y. S., & Guba, E. G., 1985). This was accomplished through thick description and triangularization of method and data sources as well as persistent observation and prolonged engagement.

Consistency has to do with reliability and dependability. These provide strategies to minimize bias and ensure that the presented research study paints an accurate picture of observed experience. A trail of documentation ensured the integrity of these characteristics by the use of audio/video recordings as well as field notes of the interviews and observed sessions. Another strategy utilized was the use of more than one “grader” of the pre/post tests and the concept maps. This showed inter-rater reliability for the study (Campbell, D. & Stanley, J., 1963; Lincoln, Y. S., & Guba, E. G., 1985).

Neutrality or being objective in quantative research corresponds to confirmability in qualitative research. While in traditional quantative research the researcher separates him/herself from the participants, the qualitative researcher immerses him/herself in the study with the participants. The explicit description of roles of the participants and researchers and their interaction during the study ensures this neutrality. The review of these roles throughout the study is vital (Campbell, D. & Stanley, J., 1963; Lincoln, Y. S., & Guba, E. G., 1985).

Open communication during and after the study with study participants (teachers, students, and researcher) and working toward establishing a working rapport with all involved reflected a sense of care. This care allowed participants to communicate honestly and openly about their experience. All of this helped to build trustworthiness in the study to focus on what actually experience was.

The basis of the concept mapping technique, which Joseph D. Novak of Cornell University developed in the 1960’s, came from the theories of David Ausubel. Ausubel, like Piaget and others, believed and stressed the importance of prior knowledge in understanding new concepts. Novak concluded, “Meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures” (Novak & Gowin, 1984). Novak and Gowin describe concept mapping as "an explicit representation of the concepts and propositions a person holds" (1984, pg.19).

Concept maps are snapshot-like glimpses of the students’ level of understanding at a point in time. As teaching and learning occur, this snapshot may change. Our goal as educators is to deepen the level of understanding. As understanding deepens, the complexity and connectedness of the students’ concept maps will increase and more links that are correct will appear. Concept mapping is a tool for assisting and enhancing many of the types of thinking of how students learn. Concept maps are visual representations of students’ knowledge and understanding and show the elaborate networks of the concepts learned. Concept maps more clearly define the ideas of the students, and provide the opportunity for the students to show relative importance of each idea and show links between ideas. Concept maps allow the addition of new information by the student as well as allowing researchers to see the complex relationships among ideas created from students’ understanding. One of the main purposes of concept mapping is to assess understanding and/or diagnose misunderstanding (Novak & Gowin, 1984).

In keeping with contemporary theories of learning, the number and correctness of the connections can imply an evaluated degree of understanding the more complex the web of connections, the deeper the understanding (Hiebert & Carpenter, 1992; Hiebert & Lefevre, 1986; Pintrich et al., 1993; Royer et al., 1993). Although it is doubtful these theorists were talking about analyzing concept maps, they were talking of understanding and sense making, which is what the concept maps are attempting to reveal (Novak & Gowin, 1984).

CHAPTER 4

What was observed?

Results & Discussion

The pressure to improve achievement at both national and international levels as well as deepen conceptual understanding in the area of mathematics is forcing the education community to look at changing instructional methods and/or technology integration. This pressure is coming from national, state, and local governments from learned societies and from other education stakeholders as schools move further into the information age. The professional education community is continuing to explore ways to meet the expectations of all these individuals (NCTM, 2000). This community, including university professors, researchers, public & private secondary administrators, teachers, and legislators along with other policy makers, is looking to tools such as CAI as a possible way to enhance mathematical understandings (Koedinger et al., 1997). The apparent agreement among stakeholders in mathematics education to reevaluate itself and teach toward conceptual understanding rather than the traditional, teacher-directed methods of instruction has moved education to the point of carefully and critically examining the future of tools such as Cognitive Tutor, a CAI program in the mathematics classroom.

Studies have shown that CAI has had a positive impact on achievement on standardized tests (Koedinger et al., 1997), on student attendance (Bracey, 1987;

Ehman & Glen, 1987; McCoy, 1996), and on student attitudes toward school and mathematics (Bracey, 1987; Ehman & Glen, 1987), but the question remains: Do students develop a deeper conceptual understanding? With an emphasis being placed on building conceptual understanding, this chapter will describe the influences on algebra 1 students development of conceptual understanding of mathematics concepts when engaged with Carnegie Learning's Cognitive Tutor, a computer-aided-instructional tool. Over the course of one semester, this study took place in a typical algebra 1 course examined how students conceptual understandings changed or deepened as described through the limited lens of concept maps. In addition, the study further examined what aspects of Cognitive Tutor influenced change in some of the students as compared to a classroom with traditional teacher directed instruction. Informants statements will be used to describe the informant's own statements as to which aspects of Cognitive Tutor influenced their conceptual understandings or impacted their sense making process.

The design of the study was intended to address issues associated with the evolutionary process of algebra 1 students' conceptual understandings and how these understandings develop in a southwestern United States suburban public high school. The guiding questions for this study were:

1.) What influences does the Cognitive Tutor CAI program have on the achievement and conceptual understandings of algebra 1 students?

2.) What factors influenced any observed gains?

3.) What factors or aspects of Cognitive Tutor do students consider having the most influence in their understandings and sense making?

In 2003 the school district first implemented Cognitive Tutor at one of its three high schools. Initially there were 2 teachers teaching the Cognitive Tutor in algebra 1 classes, but due to teacher movement/displacement only one teacher was teaching using Cognitive Tutor when the study took place.

Population and Sample.

The study occurred during the spring semester of school. The sample for the study was 120 algebra 1 students, ninety that were enrolled in a cognitive tutor section of algebra 1 and thirty in a direct instruction section taught by the same teacher. The ninety cognitive tutor students were initially surveyed during their class. Eighty-three completed the survey (a 92% return rate) of which, sixty-six students indicated a willingness to participate in the study. From this sample of sixty-six students, ten students were randomly selected from the cognitive tutor classes to participate in the informative interviews. The purpose of the survey was to find out not only who was interested in participating, but also to gain insights into their initial feelings about the Cognitive Tutor program. The interviews, at this point, were to provide the potential informants more in depth information as to their role in the study and to ascertain their overall commitment level. Of the ten selected, six key informants were chosen from the cognitive tutor (treatment) classes. This selection in conjunction with the researcher and teacher was to ensure that the group selected represented the overall population of students, with respect to gender, race, and ethnicity.

A similar process was taken with the traditional, direct instruction section (the control group). The teacher had only one section of direct instruction algebra 1 that consisted of thirty students in the class. A total of twenty-two students returned a survey (a return rate of 73%), of which only eight volunteered to be part of the study. From those, six were randomly selected to participate in the study. The selection process of all participants was made in conjunction with the teacher and the researcher. The survey used can be found in Appendix E. Each of these classes met each day for 55 minutes, 5 days per week.

The classification of the population as well as the sample of Algebra 1 students (both experimental and control) is shown in Figure 1. Their perceptions of their own ability in mathematics is shown in Figure 2.

Classification of Population and Sample				
School Year	Cognitive Tutor Classes	Cognitive Tutor Group	Direct Instruction Class	Direct Instruction Group
Freshmen	49	4	18	5
Sophomores	15	2	4	1
Juniors	2	0	0	0
Seniors	0	0	0	0

Figure 1

The classes were comprised of mainly freshmen (72%) and sophomores (22%) that saw themselves as average to below average as math students. The cooperating teacher described all of the students as “a typical algebra 1 class.”

Self Perception of Math Ability				
Perception	Cognitive Tutor Classes	Cognitive Tutor Group	Direct Instruction Class	Direct Instruction Group
Excellent	4	0	1	0
Above Average	12	1	4	1
Average	26	1	6	3
Below Average	18	3	7	2
Poor	6	1	4	0

Figure 2

The preferred schedule for Cognitive Tutor, which was used in this study, is to allow students access to the computer lab two days per week and engage the students in group/cooperative work the other three days (Carnegie, 2002). The Cognitive Tutor curriculum emphasizes student collaborative efforts within class activities and projects and work on non-routine problems. Cognitive tutor individualizes instruction by attempting to learn the students’ strengths and weaknesses to provide feedback, remediation, and assessment when it deems appropriate, as the students utilize the computer for the CAI portion of the program. Incorporating CAI or Cognitive Tutor as described fits current demands for appropriate use of technology in the effective teaching of mathematics (NCTM, 2000; ISTE, 2002).

All the students in the classes studied both (control and treatment), were pre-tested with a teacher made test that covered the objectives in the upcoming unit. Then each of the 12 student informants attended an instructional session on concept maps during which examples of concept maps were shown. Each map had concepts contained in ovals and linking words on the lines connecting the concepts (see Appendix F for examples). The students were instructed that they could draw their maps however they wished and in whatever way made sense to them. Each student then created a list of terms related to Algebra 1 and polynomials. They added these terms to a list of pre-selected terms and fashioned them all into a concept map, adding any other ideas or terms where they saw a connection.

Quantative Results.

The evaluation of the first concept maps after the students returned them revealed that overall they were "weak," and that the frustration levels of the students had begun to rise. After the initial evaluation of the concept maps all of the informants participated in a word-sort activity to clarify the instructions on the construction of the concept map. This activity assisted the informants in understanding the idea of how to construct the concept map. The word sort activity consisted of a packet that contained cards with terms written on them, the same words as the concept map examples were used in the instructional session for concept mapping. These words were selected from a topic they would be familiar with from science, however they were different from the terms of the concept map for this study. With one word on each card, several blank cards, several pieces of string, and an instruction sheet, the students completed the word sort activity (see Appendix G). The researcher, for a previous class, created this word sort activity and the decision to implement it here was to allow the informants an opportunity to see, for themselves, how terms can link to one another and relate to each other. Each student then attempted their concept map one more time and completed the task in less than an hour.

The content pre-tests and post-tests were graded and an analysis of the means was completed (see figure 3 & 4). The mean difference on the pre-test between the control group (direct instruction) and the treatment group (cognitive tutor) was found to be -1.31, which would indicate that the control and treatment groups initially show essentially no difference in their knowledge of the pre-tested material.

Group Statistics

All Classes		N	Mean	Std. Deviation
Pre-Test	.00	28	38.9286	9.56045
	1.00	83	40.2410	12.58880
Post-Test	.00	28	64.6429	9.99338
	1.00	83	73.3735	11.50579

Figure 3

Figure 4 shows that after performing the t-test on the pre-test (111 total, 28 in the direct-instruction section & 83 in the cognitive tutor sections), there was no statistically significant difference between the two groups mean scores. The direct instruction group (the control group) had a mean of 38.9 and the cognitive tutor group (the treatment group) had a mean of 40.2. These means of 38.9 and 40.2 are the average percent scores of the control group and the treatment group respectively on the pre-test.

Independent Samples Test

		t-test for Equality of Means					
		t	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Pre-Test	Equal variances assumed	-.504	109	.615	-1.31239	-6.47149	3.84671
	Equal variances not assumed	-.577	60.956	.566	-1.31239	-5.86077	3.23599
Post-Test	Equal variances assumed	-3.583	109	.001	-8.73064	-13.56040	-3.90087
	Equal variances not assumed	-3.843	53.054	.000	-8.73064	-13.28745	-4.17382

Figure 4

The post-test analysis showed that those who were in the Cognitive Tutor group (mean = 73.4) outperformed the traditional direct instruction group (mean = 64.6). In every case, in the control group as well as in the treatment group, improvement was observed from pre-test to post-test.

Similar results were found when the t-test was performed for the twelve key informants (six from the Cognitive Tutor treatment group and six from the

Traditional Direct Instruction control group) pre and post-test scores. The t-test indicated that there were no statistically significant differences between the experimental and control groups means on the pre-test. The mean of the Cognitive Tutor group pre-test was 43.3 and the mean of the traditional, direct instruction group was 40.0. (shown in Figures 5 & 6) The calculations revealed, however, a statistically significant difference on the post-test with the means of the Cognitive Tutor group and the traditional, direct instruction group were 86.7 and 71.7 respectively.

Group Statistics

Groups Used		N	Mean	Std. Deviation
Pre-Test	.00	6	40.0000	8.94427
	1.00	6	43.3333	15.05545
Post-Test	.00	6	71.6667	11.69045
	1.00	6	86.6667	10.32796

Figure 5

Independent Samples Test

		t-test for Equality of Means					
		T	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Pre-Test	Equal variances assumed	-.466	10	.651	-3.3333	-19.2628	12.5961
	Equal variances not assumed	-.466	8.138	.653	-3.3333	-19.7707	13.1041
Post-Test	Equal variances assumed	-2.355	10	.040	-15.0000	-29.1895	-.8105
	Equal variances not assumed	-2.355	9.850	.041	-15.0000	-29.2188	-.7812

Figure 6

In conducting the statistical analysis on this data, the question arose concerning the number (n) in each group: twenty-eight in the traditional direct instruction class, eighty-three in the Cognitive Tutor classes, and then six in each of the groups studied. In an attempt to equalize the groups, a t-test was performed on the sample, the control and experimental groups to the groups of six that constructed the maps to see if the difference in means was statistically significant or if the groups could be considered statistically "equivalent." Figures 3 & 4 showed us that the Cognitive Tutor population and the traditional direct instruction population were not significantly different in their knowledge at the pre-test. And Figures 7 & 8 show us that the six key informants from the traditional direct instruction group did not differ significantly from the population in which they were chosen.

Group Statistics

Traditional Group to Traditional Population		N	Mean	Std. Deviation
Pre-Test	.00	22	38.6364	9.90212
	1.00	6	40.0000	8.94427
Post-Test	.00	22	62.7273	8.82735
	1.00	6	71.6667	11.69045

Figure 7

Independent Samples Test

		t-test for Equality of Means					
		t	df	Sig. (2-tailed)	Mean Differenc e	95% Confidence Interval of the Difference	
						Lower	Upper
Pre-Test	Equal variances assumed	-.304	26	.763	-1.3636	-10.5706	7.8433
	Equal variances not assumed	-.323	8.671	.754	-1.3636	-10.9606	8.2333
Post-Test	Equal variances assumed	-2.055	26	.050	-8.9394	-17.8816	.0028
	Equal variances not assumed	-1.742	6.638	.127	-8.9394	-21.2061	3.3273

Figure 8

In figures 9 & 10 show that the 6 key informants from the Cognitive Tutor group did not differ from their population significantly either. This essentially indicates that the 12 key informants were a representative sample of the population that they were chosen from, and that each set of 6 did not differ significantly from their sampled population.

Group Statistics

Cognitive Tutor Group to Cognitive Tutor Population		N	Mean	Std. Deviation
Pre-Test	.00	77	40.0000	12.46046
	1.00	6	43.3333	15.05545
Post-Test	.00	77	72.3377	10.98996
	1.00	6	86.6667	10.32796

Figure 9

Independent Samples Test

		t-test for Equality of Means					
		T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Pre-Test	Equal variances assumed	-.622	81	.535	-3.33333	-13.98985	7.323
	Equal variances not assumed	-.528	5.547	.618	-3.33333	-19.07991	12.413
Post-Test	Equal variances assumed	-3.087	81	.003	-14.32900	-23.56379	-5.094
	Equal variances not assumed	-3.258	5.918	.018	-14.32900	-25.12778	-3.530

Figure 10

When the concepts maps were completed, they were analyzed by comparing them to an expert map constructed by the instructing teacher. The concept maps were analyzed utilizing the expert map as the basis to observe the evolution and accuracy of the students conceptual understanding as each proceeded through the study. Figures 11 & 12 indicates that both groups (experimental and control) made progress as the study progressed. Figure 11, shows that each of the groups mean number of correct connections increases with each consecutive map construction. In fact, the differences of the first and the second maps were not statistically significant when comparing the control and the treatment groups ($p<.05$).

Group Statistics

Groups Used		N	Mean	Std. Deviation
First Map	.00	6	22.0000	6.35610
	1.00	6	23.5000	5.46809
Second Map	.00	6	27.0000	5.69210
	1.00	6	32.1667	4.70815
Third Map	.00	6	35.5000	10.05485
	1.00	6	49.1667	6.30608
Forth Map	.00	6	43.1667	11.72035
	1.00	6	63.1667	9.45339

Figure 11

However, figure 11 also shows that for the third and the forth map differences did occur between the control and experimental groups that were statistically significant ($p < .05$).

Independent Samples Test

		t-test for Equality of Means					
		t	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
First Map	Equal variances assumed	-.438	10	.671	-1.500	-9.12683	6.1268
	Equal variances not assumed	-.438	9.782	.671	-1.500	-9.14996	6.1499
Second Map	Equal variances assumed	-1.713	10	.117	-5.167	-11.88606	1.5527
	Equal variances not assumed	-1.713	9.660	.119	-5.167	-11.91824	1.5849
Third Map	Equal variances assumed	-2.821	10	.018	-13.667	-24.46286	-2.8705
	Equal variances not assumed	-2.821	8.406	.021	-13.667	-24.74683	-2.5865
Forth Map	Equal variances assumed	-3.253	10	.009	-20.000	-33.69696	-6.3030
	Equal variances not assumed	-3.253	9.571	.009	-20.000	-33.78063	-6.2194

Figure 12

The analysis of the concept maps consisted of not only counting the number of connections and comparing that with the expert map, but also considering the correctness of the connections. The initial correctness was determined by comparing the students maps directly to the expert map. However, connections were found that were not on the expert map that were, after further consideration, deemed correct. This is to say that the expert map was not a "perfect map", consisting of all possible connections that could be made, but rather the expert map was comprised of the connections that the instructing teacher and researcher would find typical for algebra 1 students.

An important observation about both the control group and the experimental groups' maps was that many of the students' concept connections were low level or even trivial. In addition, nearly all of the students' maps indicated explanation or connection regarding a problem. Instead of naming concepts and the relationships connecting them, the students provided steps in a procedure. The student maps were further scrutinized to determine, if each student's problem/situation (e.g., equation, or graph) and/or steps in the procedure were accurate. The linking words were key in this analysis, as they added to the clarification of the students' understanding and the correctness of the connections. Although the evidence is not conclusive at all the stages, the concept maps do reflect that as the study progressed that students from the cognitive tutor treatment group had a better understanding of polynomials and related algebra 1 concepts.

The integration of concepts, as shown by linking one concept to another concept in another branch, rarely existed (referred to as cross-links). When students did exhibit these cross-links, most were lower level. For example, "variables can be letters or boxes," and "numbers are used to add, subtract, multiply or divide" and "coefficients are numbers" were common types cross links. Although these links were lower level, the instructing teacher confirmed that for algebra 1 students this was not out of the norm.

While conducting the analysis of the pre-tests, post-tests and the constructed concept maps for the control and experimental groups, an analysis of the pre/post-tests for the twelve key informants that participated in the concept map portion of the study and those who did not construct maps was completed. Figures 13 & 14 show the results of this analysis.

Group Statistics

Maps		N	Mean	Std. Deviation
Pre-Test	.00	99	39.6970	11.90563
	1.00	12	41.6667	11.93416
Post-Test	.00	99	70.2020	11.24675
	1.00	12	79.1667	13.11372

Figure 13

Independent Samples Test

		t-test for Equality of Means					
		T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Pre-Test	Equal variances assumed	-.541	109	.590	-1.9697	-9.1842	5.2448
	Equal variances not assumed	-.540	13.791	.598	-1.9697	-9.8028	5.8634
Post-Test	Equal variances assumed	-2.562	109	.012	-8.9647	-15.9008	-2.028
	Equal variances not assumed	-2.269	13.037	.041	-8.9647	-17.4973	-.4320

Figure 14

The results of this analysis would indicate that the 12 key informants that constructed the maps were not significantly different when it came to the pre-test, but were statistically different for the post-test scores (-8.96) as compared with those who did not construct maps.

Qualitative Results.

Once the post-test was given and the final concept map was created, each of the key informants were interviewed from the Cognitive Tutor group. The purpose of the interviews was to gain a better understanding of the informants experience more fully and to potentially illuminate key aspects of Cognitive Tutor that they perceived as having influence on their meaning making and conceptual understandings. The interviews held to the basic structure of a researcher developed interview protocol study. (see Appendix B) For the interviews the basic interview protocol structure was used, in that questions were asked however the order and direction of the interview followed the informants lead.

At the beginning of the study the researcher asked the students about their initial feelings of the Cognitive Tutor program, most of the key informants (four out of the six) expressed appreciation and were positive about their overall feelings of being part of such a new approach. When asked at the end of the study all had positive or favorable comments about the program. For example, Gemma made the comment, "It [Cognitive Tutor] let me understand how I learn math best." However, some expressed apprehensions about their next year in mathematics like when Amy said, "Sure, I did ok this year, because of this program, but what's next year going to be like? Do we have Cognitive Tutor for Geometry? NO."

Apprehension for the program and the small groups were sources of uneasiness, at least at first. Most students took about a week to learn the program and maneuver through the program.

Will said, "

> "Well you see I moved here late (3 weeks). It seemed like it took forever to catch up. I not only had to learn the math but I had to learn that program to learn the math. I felt like I was just getting' further and further behind. But ya' know when it all played out, I caught up and I really feel as if I really learned some math this year."

In addition, Gemma stated, “After the first week I wanted to switch classes, it just took too long to learn (the program). It took me about a week and a half. The counselor wouldn’t let me switch, so I stayed.”

As far as the small groups and the discussions in math class, all but one of the informants indicated that these avenues for dialog were a major positive aspect of the Cognitive Tutor program. At first, the participants in general were uneasy with the discussion/dialog about their mathematics. Amy indicated,

> “At first the small group stuff, well I didn’t like it. But as the year went on the groups helped it come together for me. I have never had a teacher do that in math before. Cognitive tutor made it easy to go to class.”

Moreover, Justin stated,

> “I was involved this year, kinda like my eighth grade teacher did. When I feel as if I am involved, then I get it. The small groups were ok. They got a lot better when I realized that the arguing I was doing everyday in there made me do better in the class.”

Justin’s statement ties into another main theme. After transcribing the interviews, it was clear that a common theme generated from the coding was how the students saw the computer program as a “teacher,” one that promoted all students to be active learners and involved learners.

Bonnie stated it this way,

> "Cognitive tutor didn't take a personal interest in me like a teacher would have. But I can say that this year I learned my math my way and then talked it out with my friends. I really hate it when I can't talk. I shut down if I cannot talk about the problems. I like the hands on part of Cognitive tutor when I feel I am doing my work instead of just sittin' and watchin'."

And Josie's comment added,

> "Cognitive tutor did give me help when I needed it, and I didn't even get my head bitten off. I guess the one thing that helped the most was I couldn't just sit back, I had to do the math."

After the analysis was completed and themes emerged, a follow up email questioned each of the interview informants, "How would you describe the best math teacher, one you have had or the characteristics of what would be the best math teacher?" This follow up also gave the informants an opportunity to add or clarify anything they felt they needed to clarify from the interview process. Figure 15 provides the list of characteristics of the best math teacher.

Characteristics of the Best Math Teacher	Cognitive Tutor Characteristic
Good Explanation.	X
Get kids Active/Involved.	X
Supportive/Offers Needed Help.	X
Shows a Personal Interest in Students.	
Examples are Relevant.	X
Hands on Approach.	X
Allows asking Questions/Why?	
Friendly & Approachable.	X
Flexible/Open to other Approaches.	
Immediate Feedback.	X
Makes class FUN/Inviting or Easy to come to Class.	X

Figure 15

Figure 15 not only shows the list of characteristics, but also indicates which characteristics the students felt Cognitive Tutor met. This list further clarifies the results of the interviews, and further substantiates the impact of the Cognitive Tutor had on the students leaving algebra 1.

Chapter 5

What does all this mean?

Analysis & Discussion.

With pressures from many segments of our society, schools are attempting to meet the calls for change in the mathematics classroom. Technological mandates and teaching for conceptual understanding are examples of imposed pressures from national organizations, state legislatures, and the federal government. By implementing computer-assisted-instruction (CAI) programs such as Cognitive Tutor from Carnegie Learning, it may be possible to meet these calls for change. The goal of this study was to focus on the following research questions:

1.) What influences does the Cognitive Tutor CAI program have on the achievement and conceptual understandings of algebra 1 students?

2.) What factors influenced any observed gains?

3.) What factors or aspects of Cognitive Tutor do students consider having the most influence in their understandings and sense making?

The quantitative analysis provided data for testing of the study's research questions and the qualitative analysis allowed for a more in-depth analysis providing a rich, thick description of the students' perceptions and feelings as to the most influential aspects of the Cognitive Tutor algebra 1 program. In this chapter we will analyze, and interpret this data and describe the implications it has on the education of our students. At the conclusion of this chapter, we will discuss the limitations and possible extensions of this research.

Quantitative Analysis.

The quantitative data of this study as presented in chapter 4 indicates that the study started with student groups that were essentially identical regarding their knowledge of the material in the unit of the study (figures 3 & 4). When a comparison was made (figures 5 & 6) between the groups of the study, no significant differences were found on the content pretest. Figures 7 & 8 show neither the group differed significantly from the sample (see figures 9 & 10). This underscores that the groups participating in the study were essentially "equal" in respect to the concepts and content that were presented during the study.

Concept maps were constructed at four different intervals as part of each group's work within the unit of study. These concept maps provided a glimpse of the students' understanding as it formed, developed, and was influenced as the study progressed. As can be seen from figures 11 & 12, both groups made more connections on the concept maps as the study progressed. However, few differences are seen on the first and second concept maps constructed by the students ($p < .05$). This most likely is due to the fact that both groups started out nearly equal in their knowledge and conceptual understandings of algebra 1 concepts and had just learned how to construct concept maps. It is not surprising that with each construction of a map students in both groups not only understood more material but understood better how to more effectively construct a concept map. Most significant is that with each successive construction the mean difference between the control and treatment groups increased. More specifically with the third and fourth constructions, the experimental (CAI group) out performed the control group at a significant level ($p < .05$).

Not surprising is that the Cognitive Tutor group not only outperformed the direct instruction group with respect to the number of connections made on the concept maps, but also on the unit post-test ($\overline{X} = 86.67$ to $\overline{X} = 71.67$). The number of correct connections on the concept maps and the post-test scores were both statistically significant, indicating that the Cognitive Tutor program had made a positive impact on the conceptual understanding of the study participants. Specifically, the students utilizing the complete CAI program, Cognitive Tutor, made more correct connections in their maps and outscored the traditional direct instruction group on the post-test. Therefore these results would indicate the Cognitive Tutor (treatment) group developed a deeper understanding of the concepts presented in this algebra 1 unit.

Qualitative Analysis.

The qualitative portion of his study sought to examine the factors and aspects of the CAI program Cognitive Tutor that the students felt had the most significant influence on their developing conceptual understandings and sense making. All six interviewed shared key aspects that illuminate the influence Cognitive Tutor had on them during the study. The comfort level with computers and technology that all informants showed confirms Tapscott's (1998) statements about this generation and their ability to learn with technology. Growing up digital, this generation shows an ease of learning with technology that has not been seen in any other generation (Tapscott, 1998). This may have influenced the positive impact on the pre and post-tests and concept map constructions and thus the overall effectiveness of this program on these students.

A more significant observation was the appreciation and credit given to the small group discussion and cooperative learning aspects of the complete Cognitive Tutor. This aspect is what sets Cognitive Tutor apart from other CAI programs. The intent is that students' immersion into the activities encourages discussion, explanation, connection, and justification of their mathematics to previously learned concepts. This illuminating factor of sharing, discussing, and evaluating our own mathematics is well supported by recent research throughout mathematics education (Doll, 1993; Applebee, 1996; Yakel & Cobb, 1996; Piaget, 1985). Amy and Bonnie, two of the informants, commented directly on the importance of the small group discussion aspect of Cognitive Tutor.

Amy indicated,

> "At first the small group stuff, well I didn't like it. But as the year went on the groups helped it come together for me.

> I have never had a teacher do that in math before.
> Cognitive tutor made it easy to go to class."

Bonnie stated it this way,

> "Cognitive tutor didn't take a personal interest in me like a teacher would have. But I can say that this year I learned my math my way and then talked it out with my friends. I really hate it when I can't talk. I shut down if I cannot talk about the problems. I like the hands on part of Cognitive tutor when I feel I am doing my work instead of just sittin' and watchin'."

Cognitive Tutor and CAI's have the potential to not only increase student achievement (see figures 5 & 6), but also serve as a means of deepening conceptual understanding (see figures 11 & 12). This confirms Koedinger & Sueker's (1996) work where they indicated that CAI's can provide an example of effective instructional practices.

The six key informants from the cognitive tutor (treatment) group described the cognitive tutor program in much the same way they would their ideal or best math teacher. The informants described the best math teacher as: one who gives good explanation gets kids Active/Involved; is supportive/offers needed help; shows a personal interest in their students; teaches with good examples; teaches with a 'hands-on' approach; allows you to ask 'Why?'; is friendly, and flexible; makes class and school fun; offers immediate feedback. Of these characteristics, the informants indicated that eight of the eleven (73%) characteristics were also characteristics of the Cognitive Tutor program, and that the best teachers they have ever had only possessed at best six of the eleven (55%) (See figure 15).

Although this study cannot provide conclusive evidence that concept maps can differentiate between the more subtle levels of understanding, the analysis did provide information about students' understanding that is not readily gained from traditional pen-and-paper tests. Typically mathematics teachers will attempt to locate the incorrect "step" in a problem but this does not always explain "why" a student made the mistake. Concept maps can shed valuable light into this sort of situation. By utilizing concept maps, students and teachers can actually catch a glimpse what the students are thinking. Many times a teacher will ask a student to explain some aspect of their mathematics or their thinking, and the student will not be able to do so, with the concept map, the student as well as the teacher can observe the student's thought progression together. Concept maps, therefore, can provide important information about conceptual understanding and can play a useful role not only in the mathematics researcher's repertoire of tools, but also in the mathematics teachers own "toolbox."

Implications.

Cognitive Tutor is an example of a computer-assisted-instruction program that meets the new legislative mandates and calls for change in the teaching of mathematics. Yet if taken only at face value as just another CAI program, Cognitive Tutor seems to be nothing more than a behaviorist, spiral curriculum on the computer. It would seem that the idea of learning on the computer does open the computer savvy generation's minds to school and learning. The question then is why does Cognitive Tutor stand out from other CAI programs? The cooperative learning and small group focus of Cognitive Tutor is a key that sets it apart from other CAI programs. Through these groups students are engaged in sense making, for example when Amy said, "The groups is where it came together for me;" or when Justin stated, "They (the small groups) got better when I realized that the arguing I was doing in them made me do better." This aspect of the Cognitive Tutor program is where the real understanding takes place, and where students construct and grow in their conceptual understandings.

The cooperative small groups with rich problem tasks allow students a place for mathematical conversations to start and to keep going (Applebee, 1996). What teachers need to keep in mind, as they become facilitators of these conversations, is to seize the opportunity to bring in culturally significant topics (Applebee, 1996). Instead of following the "production model" of scripted problems that is leading our students down a path that says education exists only to make more money, and for our students to make it in the economic marketplace of the 21st century (ISTE, 2000; NCTM, 1989, 2000).

The economic related by-products of a technology rich education alleged by national organizations (NCTM, 2000; ISTE, 2000) are possible. However, the question is, whether or not that our sole aim in educating our young people? Are we teaching them for the solitary purpose of a better paying job and making more money than the previous generation? This would be to have our students adapt or conform to the world and therefore stifle their creativity and rob them of their free thought (Che, 2005). To the contrary, a technology rich education should provide our children with an understanding of a valuable tool, to explore beyond the boundaries of the current curriculum that schools impose on them. Technology is a means to allow students to see what they cannot otherwise see from the confines of the typical American classroom to look outside of themselves to see what is "really" happening.

The results of this study would indicate that Cognitive tutor clearly meets several of the goals of NCTM and ISTE and the mandates of No Child Left Behind. The primary focus implementing research based reform in the mathematics classroom while making technology accessible and a key component of algebra 1 classrooms, focusing the algebra 1 curriculum on our students' personal lives is readily apparent. However, Cognitive Tutor could go so much further by taking our students to a higher level of awareness via the avenue of the cooperative learning and small group discussions. By changing the questions from "real world" or jobs related to rich questions that are real to the students, real to their interests, thus truly, creating questions that Matney (2005), described as authentic, our students would be taken to a new level of interest in their education and their mathematics. To be authentic according to Matney (2005) the problem situations chosen need to be of interest to our students, not just merely problems "that involved mathematics by an applied approach to a real-world context" (p. 13). Josie's statement supports this when she said, "I am not going to be a carpenter. I am not at all going to sell t-shirts. No one in my family is one. Is this only carpenter or t-shirt math?"

Part of the trouble with learning mathematics at school is that it is not like mathematics in the real world. That is where the infamous question, "Where am I going to use this?" originates in the vast majority of mathematics classrooms. In the real world, there are engineers who use mathematics to make/design bridges or machines. There are scientists who use mathematics to explain scientific phenomenon, to describe how atoms work, or to discover new medicines to cure diseases. There are bankers who use mathematics to project future earnings and possibly make more money for their constituents. However, it is different for children in school. What can they make with mathematics? They typically sit in class and they write numbers on pieces of paper, mimicking their teacher all the while crossing their fingers that somehow they will make sense of it all. Carnegie Learning with Cognitive Tutor has tried to find ways that children can use mathematics to make something, something interesting, so that the children's relationship to mathematics is more like that of an engineer, a scientist, or a banker. Carnegie Learning is trying to find these ways by use of technology to enable children to use mathematical knowledge as well as knowledge and experiences gained previously to construct something new, not just store it in their heads so that later it will be good for them in some way.

Possible future Research.

This study examined Cognitive Tutor as a complete program, with the CAI component as well as the small group, cooperative learning component. The analysis discussed here has clearly shown that the complete Cognitive Tutor program has shown increases in achievement as well as conceptual understanding shown by concept maps in algebra 1 students. A perplexing question that remains is, "Would the traditional, direct instruction students (control group) see similar increases on their post-tests and numbers of concept map connections as seen in the Cognitive Tutor students (treatment group), if they had similar small group, cooperative learning activities?" The analysis of the students' comments on the small groups and the cooperative learning aspect of Cognitive Tutor showed the significance that the students put on this aspect. Was it the CAI portion or the small group discussions of Cognitive Tutor that had the impact on the students off this study?

Additionally, a correlation observed when examining the pre/post tests of traditional/direct instruction classes yielded that the sub-group that constructed the concept maps throughout the study had a statistically significant mean difference when compared to those who did not construct maps throughout the study. (See figures 16 & 17)

Group Statistics

Traditional Classes Used compared with Sample		N	Mean	Standard Deviation
Pre-Test	.00	16	33.7500	9.57427
	1.00	6	40.0000	8.94427
Post-Test	.00	16	61.2500	8.85061
	1.00	6	71.6667	11.69045

Figure 16

Independent Samples Test

Traditional Classes Used compared with Sample		t-test for Equality of Means					
		T	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Pre-Test	Equal variances assumed	-1.386	20	.181	-6.250	-15.657	3.1573
Post-Test	Equal variances assumed	-2.257	20	.035	-10.417	-20.042	-.7910

Figure 17

This data helps to ask another question, "If all the students in the sample were to have constructed the concept maps, would they have seen similar increases in their post-test scores?"

These two questions not only beckon us to further this research, but they also let us know that with the data realized in this study, along with the accompanying analysis, we cannot, without a doubt say what individual aspect impacted the post-test scores of the students in this study the most. The data and analysis presented in this study do not provide clear evidence that the gains observed can be attributed to any one factor. Was it the computers (CAI only)? Was it the small group/cooperative learning problem solving aspect of Cognitive

Tutor? Was it due to teacher motivated to a new approach with a new tool? Or were the gains due to the Hawthorne effect? This study cannot say any one caused the gains. Nevertheless, we can say that in this case the complete Cognitive Tutor program as prescribed from Carnegie Learning not only helped the students of this study achieve higher scores but also allowed for deeper conceptual understanding to develop when compared with traditional direct instruction.

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APPENDIX A

EDMOND PUBLIC SCHOOLS

Empowering all students to succeed in a changing society

To: Doctoral Committee of
Candidate William Arbuckle

From: David Goin, Ed.D. Superintendent
Edmond Public Schools

Date: July 21, 2004

Re: Doctoral Dissertation Study

This letter is provided to acknowledge approval and support from the Edmond Public Schools for Mr. William Arbuckle's dissertation research strategies. We believe that his survey of high school students to assess issues surrounding students' cognitive development through use of the 'Cognitive Tutor' program may provide meaningful feedback to assist with program development.

APPENDIX B

SANTA FE HIGH SCHOOL

1901 S. W. 15th STREET EDMOND, OKLAHOMA 73013

(405) 340-2230 Fax (405) 340-2240 Counseling Office (405) 330-3317 Counseling Office Fax (405) 330-7348

"Educating students to become successful and productive citizens"

August 18, 2004

To Whom It May Concern:

When Bill Arbuckle contacted me during the 2003-2004 school year regarding researching our computer-based Algebra I classes, I fully supported the study he conducted during the spring term.

Very truly yours,

Vicki Simpson

Vicki Simpson
Principal

<u>APPENDIX C</u>

PROTOCOL #

FY

INSTITUTIONAL REVIEW BOARD PROGRESS REPORT FORM FOR APPROVED USE OF HUMAN SUBJECTS IN A RESEARCH INVESTIGATION

Project Title: **Perceptions and Attitudes toward Mathematics and Cognitive Tutor/Computer Aided Instruction Program in the Algebra 1 Classroom and resulting Achievement.**

Principal Investigator(s): **William J. Arbuckle**

Status of the Study (Please check one of the Following):

ACTIVE continuing to enroll subjects	ACTIVE, but closed to new subject enrollment	COMPLETED please inactivate
	XXX	

APPROVED STUDY SITE(S): ___**Edmond Santa Fe High School**____

NUMBER OF SUBJECTS ENROLLED IN THE PAST 12 MONTHS: _20_

NUMBER OF SUBJECTS ENROLLED TO DATE (since IRB approval): _20

SUMMARY OF STUDY RESULTS

(Please summarize study results since your last review. Use more pages as needed.)

I first surveyed the classes to select my participants and followed that with the Pre-test. I then met with the participants either in group or individual formats over a period of 8 weeks. I observed them in class as well as on the computer. I then followed up the observations with interviews and meetings for the purpose of constructing the concept maps. After this was done I then followed up with the Post-test.

Please list any adverse effects to study subjects and the dates of notification to the IRB.

With this study there were no adverse effects to the participants.

If you checked "ACTIVE, continuing to enroll subjects" above

A Copy of Each Currently Used Consent Form Must Be Included With This Progress Report

Principal Investigator Signature:

____

(You must return a signed copy of this form to the IRB. Substitute signatures are not allowed.)

Phone: __405-229-3935_______ Date: ___01-03-2005___

INSTITUTIONAL REVIEW BOARD APPLICATION
FOR APPROVAL OF THE USE OF HUMAN SUBJECTS IN AN INVESTIGATION CONDUCTED ON THE NORMAN CAMPUS AND/OR BY UNIVERSITY OF OKLAHOMA FACULTY, STAFF OR STUDENTS

Your application for approval of the use of human subjects should consist of eleven (11) copies* of three parts:

PART I - A COMPLETED APPLICATION FORM
PART II - A DESCRIPTION OF YOUR RESEARCH STUDY
PART III - SUBJECT'S INFORMED CONSENT FORM FOR PARTICIPATION IN YOUR STUDY

You should attach supplementary information pertinent to this study that will help the board members in their review of your application, i.e., questionnaires, test instruments, letters of approval from cooperating institutions or/and organizations. Failure to submit these items will only delay your review.

Applications are due not later than the 1st **day of the month in which you wish the proposed project reviewed**

Please return completed proposals to:

Campus Mail:
Office of Research Administration
Buchanan Hall, Room 314

U.S. Mail:
Office of Research Administration
1000 Asp Avenue, Room 314
Norman, Oklahoma 73019-0430

Please call the ORA at 325-4757 and ask for the IRB if you have any questions. Please type your responses.

PART I - APPLICATION FORM

1. **Principal Investigator:**

Name William J. Arbuckle

Department ILAC Mathematics Education

Campus Phone No. (405) 229-3935 E-mail Address mrbill@the5arbuckles.com

If you are a student, provide the following information:

Daytime Phone No. (if different from above) (405) 340-2875

Mailing Address_ 2413 Apple Way Edmond, OK 73013
Faculty Sponsor: Dr. M. Jayne Fleener
Department EDUC/Instructional Leadership/Academic Curriculum
Sponsor's Phone No. (405) 325 -1081 E-mail Address fleener@ou.edu

Co-Principal Investigator(s) (Please include name, department, and campus phone number)

Signatures:
Principal Investigator
Co-Principal Investigator(s)

Faculty Sponsor (if student research project)

If you believe your use of human subjects would be considered exempt from review or qualifies for expedited review as defined in Sections 4 and 12 of the University of Oklahoma Norman Campus Policy and Procedures for the Protection of Human Subjects in Research Activities, you may submit two (2) copies of this application for initial review. If full Board review is required, you will be required to submit nine (9) additional copies.

2. Project Title: **Perceptions and Attitudes toward Mathematics and Cognitive Tutor/Computer Aided Instruction Program in the Algebra 1 Classroom and resulting Achievement.**

3. Project Time Period: From **November 2002 to August 2003**

4. Previous Institutional Review Board-Norman Campus Approval for this project?
Yes ____ No **XX**
If yes, please give date of the action

5. Are you requesting funding support for this project?
Yes ____ No **XX** If yes, please give sponsor's name

6. Description of Human Subjects:

Age Range **14 - 18** Gender (please check one): __Males; __Females; **XX** Both
Number of Subjects _ **20 - 30**
Special Qualifications _ All are to be students in specific classes using the Cognitive Tutor Program.

Source of Subjects and Selection Criteria
The source of the subjects is Edmond Santa Fe High School Algebra 1 Students

Please check any protected groups included in this study.

___ Pregnant Women	___ Fetuses	**X** Children
___ Mentally Disabled	___ Elderly	
___ Mentally Retarded	___ Prisoners	

PART II - DESCRIPTION OF THE STUDY

To assist Institutional Review Board members in conducting their review of your application, please prepare a brief (1-3 page) description of the study you plan to conduct, including the following information:

A. Purpose/Objectives

Explain the overall purpose of your study and its primary objectives, including the importance of the knowledge expected to result.

B. Research Protocol

Describe the study and procedures you will use, including a step-by-step description of the procedures you plan to use with your subjects.

C. Confidentiality

Briefly describe the procedures you will use to assure confidentiality of the data you collect from your subjects, specifically address whether subjects will be identifiable from raw and/or refined data, how data will be protected from non-project personnel (e.g., stored in locked cabinets), whether the identifiable data will be destroyed when no longer needed, and whether project publications (theses, papers, videotapes, etc.) will allow identification of individual subjects.

D. Subject Benefit/Risk

Describe both the potential benefits and risks to subjects and society that may result from their participation in this project.

PART III - INFORMED CONSENT FORM

No investigator may involve a human being as a subject in research unless the investigator has obtained the legally effective informed consent of the subject and/or the subject's legally authorized representative. An investigator shall seek such consent only under circumstances that provide the prospective subject and/or the subject's representative sufficient opportunity to consider whether or not to participate and that minimize the possibility of coercion or undue influence. Two copies of the Informed Consent Form should be provided, one for the subject to retain for his/her records and the signed form which is returned to the researcher.

A consent form must be written in **lay language**, easily comprehensible to the person who is being asked to sign it as a legal indication of voluntary participation in the proposed study and every effort should be made to limit the consent form to one page including space for the participant's signature. No informed consent form may include any language through which the subject or the subject's representative is made to waive or appear to waive any of the subject's legal rights, or which releases or appears to release the investigator, the sponsor, the University, or its agents from liability for negligence. The following outline summarizes the minimum information that must be included in a consent form. Additional elements of informed consent may be requested or required by the Institutional Review Board where appropriate, depending upon the special circumstances of a particular research protocol.

I. HEADING

The form should be clearly titled Informed Consent Form for research being conducted under the auspices of the University of Oklahoma-Norman Campus.

II. INTRODUCTION

Begin with a statement that identifies the study by title, sponsor, and principal investigator and indicate that the document is an individual's consent for participation in that research project.

III. DESCRIPTION OF THE STUDY

Describe the purposes of the research in language which is appropriate considering the age, educational level, etc. of the subject pool. Provide a straightforward, easily understandable description of the procedures to be followed in the study; identifying any procedures which are experimental. Specify the amount of time required for the subject's participation.

IV. POTENTIAL RISKS AND BENEFITS OF PARTICIPATION

A. Risks

Identify any reasonably foreseeable risks or discomforts to the subject as a result of participation in the study, and describe measures that will be taken to minimize any risk or discomfort. If no foreseeable risks beyond those present in normal everyday life are anticipated, a statement to that effect should be included.

B. Benefits

Describe any benefits to the subject or to others that may reasonably be expected from the research, including therapeutic benefits, new knowledge that leads to improved conditions, payment for participation in the study, etc.

V. SUBJECT'S ASSURANCES

A. Conditions of Participation

Include a statement that the subject's participation is voluntary, refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled, and the subject may discontinue participation at any time without penalty or loss of benefits to which the subject is otherwise entitled.

For studies involving only adults, include a statement such as: *To participate, you must be 18 years of age or older.*

For studies involving minor children, a parental consent form must be included <u>in addition</u> to the participant’s assent form.

B. Confidentiality

Include a statement describing the extent, if any, to which confidentiality of records identifying the subject will be maintained. Avoid use of the term anonymous if there is any reasonable possibility that subject’s identities can be established. If the research is anonymous (i.e., a survey returned in pre-addressed postage paid envelope with no way of identifying the participant), a cover letter which clearly addresses all the components of informed consent may be substituted for a signed consent form. In the case of a telephone survey, a script clearly addressing all the components of informed consent should be submitted for review.

C. Compensation for Injury

For research involving more than minimal risk, explain whether or not any compensation or medical treatment is available if injury occurs. If compensation or treatment will be provided, describe the nature of the compensation and/or treatment. If no compensation will be available, make that clear in the consent form. Explain how the subject can obtain additional information if necessary.

D. Course Credit/Compensation for Participation

If the subject is to receive course credit/compensation for participation, state clearly the amount of credit/compensation to be received and what level of participation is required to receive credit/compensation. Include the statement: *If*

I am participating in this research project to obtain course credit and I decide to withdraw from participating, I might not get the course credit associated with the research project.

E. Video/Audio Taping of any Research Activities

If any activities are to be audio/video taped, state such. Include statements regarding the subject's right to refuse to allow such taping without penalty or prejudice.

F. Use of Electronic Media for Informed Consent

Informed consent is required for projects utilizing electronic means for collecting research data such as Internet surveys, chat rooms and email. Electronic informed consent forms are accepted.

G. Contacts for Questions about Research Subject's Rights

Include a statement identifying by name and phone number of the person whom the subject may contact with questions about the research. A statement directing inquires about rights, as a research participant to be made to the Office of Research Administration at (405) 325-4757 is a required component of informed consent.

VI. SIGNATURES/DATES

Include the statement: *I hereby agree to participate in the above-described research. I understand my participation is voluntary and that I may withdraw at any time without penalty or loss of benefits.*

Informed consent must be documented by the signature of the subject on subject's informed consent form. When necessary, a separate form also should be provided for the subject's legally authorized representative or guardian. A space to indicate the date signed should be included on all informed consent forms.

Consent to participate in research being conducted under the auspices
of the University of Oklahoma (Norman)

Perceptions and Attitudes toward Mathematics and Cognitive Tutor/Computer Aided Instruction Program in the Algebra 1 Classroom and resulting Achievement.

Principle Interviewer : William J. Arbuckle
Sponsor : Dr. M. Jayne Fleener, Associate Dean of Education
Instructional Leadership/Academic Curriculum

If you have questions regarding your rights as a research participant, please call the University of Oklahoma,
Office of Research Administration at (405) 325-4757

Purpose: As a part of a project to study students perceptions and attitudes toward their experience with Computer Aided Instruction (Cognitive Tutor), you are asked to be interviewed (approximately 30 - 60 minutes). Please respond to each question in the context of your role as a teacher, in your particular school. The interview will be audio recorded. You have the right to refuse audio recording without penalty or prejudice.

Confidentiality: Your name will in no way be used in connection with the research or publications derived from the research. The interviews will be coded S1, T1, S2, T2, S3, ...etc. to match audio data with that of the interview protocol. The audio tapes and the interview protocol along with any other documentation involved in the study will be locked and stored at the residence of the principle interviewer. Once the research is completed all audio recordings will be destroyed.

Potential Risk to You: None foreseeable beyond those present in everyday life.

Potential Benefits to You: A special note is made here of stating to let you know that permission has been obtained from Santa Fe High School as well as Edmond Public Schools for this research study. No other benefits are foreseeable beyond those present in normal everyday life. and those that may occur by participating in a study that may help others.

Please check one box.
Check here if it is OK to Audio tape our interview. >>>>>>>>>> ☐

Check here if it is ***NOT*** OK to Audio tape our interview. >>>>>> ☐

I, (print your full name) ____ agree to participate in a program of research being conducted by William J. Arbuckle.

I acknowledge that the procedures and expectations of the research have been fully explained to me, that my participation is voluntary and that I may discontinue from participation at any time ***without penalty*** and that William J. Arbuckle has offered to answer any questions I may ask about the procedures. I am aware of the contact information below where I call in reference to any aspect of this research study.
I voluntarily consent to take part in the research project.

____________________ ____________________________________
(Date) (Signature of Teacher Participant)

Contact Information

William J. Arbuckle	Dr. M. Jayne Fleener (Sponsor)	***PHSC 925***
mrbill@the5arbuckles.com	fleener@ou.edu	***(405) 325-6711***
(405)229-3935	(405) 325-1081	

PART II -- Description of the Study

A. Purpose/Objectives:

The purpose of this study is to identify perceptions and attitudes among student that have encountered a similar experience (Algebra 1 with Cognitive Tutor - Computer Aided Instruction). A critical review of any of these perceptions and attitudes may provide strategies that will allow the schools, the administrators, and the teachers more flexibility when implementing, and evaluating the effectiveness of a non-traditional Algebra 1 classroom.

B. Research Protocol:

I will be using descriptive interviews with individuals that are experiencing an Algebra 1 classroom with Cognitive Tutor Computer Aided Instruction while in high school. These interviews will be done face-to-face and audio-recorded. Interview Protocol Attached. The students will be randomly sellected from the seven possible sections of this class at Santa Fe High School. In addition several classroom observations may be included. These observations will be done with the least amount of interruption as possible, as to limit disruption and allow class to be as it would be normally. Video tapes could be made of these sessions for later review.

C. Confidentiality:

Your name will in no way be used in connection with the research or publications derived from the research. The interviews will be coded S1, S2, S3, ...etc. to match audio data with that of the interview protocol. The audio tapes and the interview protocol along with any other documentation involved in the study will be locked and stored at the residence of the principle interviewer. Once the research is completed all audio recordings will be destroyed.

D. Subject Benefit/Risk:

There are no foreseeable risks or benefits beyond those present in normal everyday life and those that may occur by participating in a study that may help others. Because of the confidentiality of the research project there is near zero risk for the participants.

Consent to participate in research being conducted under the auspices
of the University of Oklahoma (Norman)

Perceptions and Attitudes toward Mathematics and Cognitive Tutor/Computer Aided Instruction Program in the Algebra 1 Classroom and resulting Achievement.

Principle Interviewer : William J. Arbuckle
Sponsor : Dr. M. Jayne Fleener, Associate Dean of Education
Instructional Leadership/Academic Curriculum

If you have questions regarding your rights as a research participant, please call the University of Oklahoma,
Office of Research Administration at (405) 325-4757

Purpose: As a part of a project to study students perceptions and attitudes toward their experience with Computer Aided Instruction (Cognitive Tutor), you are asked to be interviewed (approximately 30 - 60 minutes). Please respond to each question in the context of your role as a student, in your particular school. The interview will be audio recorded. You have the right to refuse audio recording without penalty or prejudice.

Confidentiality: Your name will in no way be used in connection with the research or publications derived from the research. The interviews will be coded S1, S2, S3, ...etc. to match audio data with that of the interview protocol. The audio tapes and the interview protocol along with any other documentation involved in the study will be locked and stored at the residence of the principle interviewer. Once the research is completed all audio recordings will be destroyed.

Potential Risk to You: None foreseeable beyond those present in everyday life.

Potential Benefits to You: A special note is made here of stating to let you know that permission has been obtained from Santa Fe High School as well as Edmond Public Schools for this research study. No other benefits are foreseeable beyond those present in normal everyday life. and those that may occur by participating in a study that may help others.

Please check one box.
Check here if it is OK to Audio tape our interview. >>>>>>>>>> ☐

Check here if it is ***NOT*** OK to Audio tape our interview. >>>>>> ☐

I, (print your full name) ____ , state that I am _________ years of age and agree to participate in a program of research being conducted by William J. Arbuckle.

*** If you are under the age of 18, you must also obtain permission from your parent/legal guardian before you can participate in this research project. Please use the Parent/Legal Guardian Permission Form to obtain permission. If you are 18 years old and wish to participate, you must sign the informed consent form."*

I acknowledge that the procedures and expectations of the research have been fully explained to me, that my participation is voluntary and that I may discontinue from participation at any time ***without penalty*** and that William J. Arbuckle has offered to answer any questions I may ask about the procedures. I am aware of the contact information below where I call in reference to any aspect of this research study.
I voluntarily consent to take part in the research project.

_____________________ ____
(Date) (Signature of Participant)

Contact Information

William J. Arbuckle	Dr. M. Jayne Fleener (Sponsor)	***PHSC 925***
mrbill@the5arbuckles.com	fleener@ou.edu	***(405) 325-6711***
(405)229-3935	(405) 325-1081	

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The purpose of this study is to identify perceptions and attitudes among student that have encountered a similar experience (Algebra 1 with Cognitive Tutor - Computer Aided Instruction). A critical review of any of these perceptions and attitudes may provide strategies that will allow the schools, the administrators, and the teachers more flexibility when implementing, and evaluating the effectiveness of a non-traditional Algebra 1 classroom.

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C. Confidentiality:

Your name will in no way be used in connection with the research or publications derived from the research. The interviews will be coded S1, S2, S3, ...etc. to match audio data with that of the interview protocol. The audio tapes and the interview protocol along with any other documentation involved in the study will be locked and stored at the residence of the principle interviewer. Once the research is completed all audio recordings will be destroyed.

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There are no foreseeable risks or benefits beyond those present in normal everyday life and those that may occur by participating in a study that may help others. Because of the confidentiality of the research project there is near zero risk for the participants.

Assent to participate in research being conducted under the auspices
of the University of Oklahoma (Norman)

Perceptions and Attitudes toward Mathematics and Cognitive Tutor/Computer Aided Instruction Program in the Algebra 1 Classroom and resulting Achievement.

Principle Interviewer : William J. Arbuckle
Sponsor : Dr. M. Jayne Fleener, Associate Dean of Education
Instructional Leadership/Academic Curriculum

If you have questions regarding your rights as a research participant, please call the University of Oklahoma,
Office of Research Administration at (405) 325-4757

Purpose: As a part of a project to study students perceptions and attitudes toward their experience with Computer Aided Instruction (Cognitive Tutor), you are asked to be interviewed (approximately 30 - 60 minutes). Please respond to each question in the context of your role as a student, in your particular school. The interview will be audio recorded. You have the right to refuse audio recording without penalty or prejudice.

Confidentiality: Your name will in no way be used in connection with the research or publications derived from the research. The interviews will be coded S1, S2, S3, ...etc. to match audio data with that of the interview protocol. The audio tapes and the interview protocol along with any other documentation involved in the study will be locked and stored at the residence of the principle interviewer. Once the research is completed all audio recordings will be destroyed.

Potential Risk to You: None foreseeable beyond those present in everyday life.

Potential Benefits to You: A special note is made here of stating to let you know that permission has been obtained from Santa Fe High School as well as Edmond Public Schools for this research study. No other benefits are foreseeable beyond those present in normal everyday life. and those that may occur by participating in a study that may help others.

Please check one box.

Check here if it is OK to Audio tape our interview. >>>>>>>>>> ☐

Check here if it is ***<u>NOT</u>*** OK to Audio tape our interview. >>>>>> ☐

I, (print your full name) ____,
state that I am _________ years of age and agree to participate in a program of research being conducted by William J. Arbuckle.

*** If you are under the age of 18, you must also obtain permission from your parent/legal guardian before you can participate in this research project. Please use the Parent/Legal Guardian Permission Form to obtain permission. If you are 18 years old and wish to participate, you must sign the informed consent form."*

I acknowledge that the procedures and expectations of the research have been fully explained to me, that my participation is voluntary and that I may discontinue from participation at any time ***<u>without penalty</u>*** and that William J. Arbuckle has offered to answer any questions I may ask about the procedures. I am aware of the contact information below where I call in reference to any aspect of this research study.

I voluntarily consent to take part in the research project.

_____________________ ______________________________________

(Date) (Signature of Participant)

Contact Information

William J. Arbuckle	Dr. M. Jayne Fleener (Sponsor)	***PHSC 925***
mrbill@the5arbuckles.com	fleener@ou.edu	***(405) 325-6711***
(405)229-3935	(405) 325-1081	

PART II -- Description of the Study

A. Purpose/Objectives:

The purpose of this study is to identify perceptions and attitudes among student that have encountered a similar experience (Algebra 1 with Cognitive Tutor - Computer Aided Instruction). A critical review of any of these perceptions and attitudes may provide strategies that will allow the schools, the administrators, and the teachers more flexibility when implementing, and evaluating the effectiveness of a non-traditional Algebra 1 classroom.

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I will be using descriptive interviews with individuals that are experiencing an Algebra 1 classroom with Cognitive Tutor Computer Aided Instruction while in high school. These interviews will be done face-to-face and audio-recorded. Interview Protocol Attached. The students will be randomly sellected from the seven possible sections of this class at Santa Fe High School. In addition several classroom observations may be included. These observations will be done with the least amount of interruption as possible, as to limit disruption and allow class to be as it would be normally. Video tapes could be made of these sessions for later review.

C. Confidentiality:

Your name will in no way be used in connection with the research or publications derived from the research. The interviews will be coded S1, S2, S3, ...etc. to match audio data with that of the interview protocol. The audio tapes and the interview protocol along with any other documentation involved in the study will be locked and stored at the residence of the principle interviewer. Once the research is completed all audio recordings will be destroyed.

D. Subject Benefit/Risk:

There are no foreseeable risks or benefits beyond those present in normal everyday life and those that may occur by participating in a study that may help others. Because of the confidentiality of the research project there is near zero risk for the participants.

Parent/Legal Guardian Permission Form for research being conducted under the auspices of the University of Oklahoma-Norman Campus

Perceptions and Attitudes toward Mathematics and Cognitive Tutor/Computer Aided Instruction Program in the Algebra 1 Classroom and resulting Achievement.

Principle Interviewer : William J. Arbuckle
Sponsor : Dr. M. Jayne Fleener, Associate Dean of Education
Instructional Leadership/Academic Curriculum

If you have questions regarding your rights as a research participant, please call the University of Oklahoma, Office of Research Administration at (405) 325-4757

Purpose: As a part of a project to study students perceptions and attitudes toward their experience with Computer Aided Instruction (Cognitive Tutor), your son/daughter are asked to be interviewed (approximately 30 - 60 minutes). Please respond to each question in the context of their role as a student. The interview will be audio recorded. You have the right to refuse audio recording without penalty or prejudice.

Confidentiality: Your son/daughter's name will in no way be used in connection with the research or publications derived from the research. The interviews will be coded S1, S2, S3, ...etc. to match audio data with that of the interview protocol. The audio tapes and the interview protocol along with any other documentation involved in the study will be locked and stored at the residence of the principle interviewer. Once the research is completed all audio recordings will be destroyed.

Potential Risk to You: None foreseeable beyond those present in normal everyday life.

Potential Benefits to You: A special note is made here of stating to let you know that permission has been obtained from Santa Fe High School as well as Edmond Public Schools for this research study. No other benefits are foreseeable beyond those present in normal everyday life. and those that may occur by participating in a study that may help others.

Please check one box.

Check here if it is OK to Audio tape our interview. >>>>>>>>> ☐

Check here if it is ***NOT*** OK to Audio tape our interview. >> ☐

I, (print your full name) ________________________________, state that I am the Parent/Guardian of _____________________________________ and agree Voluntarily to give consent for my son/daughter to participate in a program of research being conducted by William J. Arbuckle.

I acknowledge that the procedures and expectations of the research have been fully explained to me, that my consent is voluntary and that I may withdraw my son/daughter from participation at any time ***without*** penalty. Any questions about the research and its procedures can be addressed by any of the following contacts at any time. (Contact Information is below.)

____________________ ____________________________________

(Date) (Signature of Parent/Legal Guardian)

Contact Information

William J. Arbuckle	Dr. M. Jayne Fleener (Sponsor)	***PHSC 925***
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PART II -- Description of the Study

A. Purpose/Objectives:

The purpose of this study is to identify perceptions and attitudes among student that have encountered a similar experience (Algebra 1 with Cognitive Tutor - Computer Aided Instruction). A critical review of any of these perceptions and attitudes may provide strategies that will allow the schools, the administrators, and the teachers more flexibility when implementing, and evaluating the effectiveness of a non-traditional Algebra 1 classroom.

B. Research Protocol:

I will be using descriptive interviews with individuals that are experiencing an Algebra 1 classroom with Cognitive Tutor Computer Aided Instruction while in high school. These interviews will be done face-to-face and audio-recorded. Interview Protocol Attached. The students will be randomly selected from the seven possible sections of this class at Santa Fe High School. In addition several classroom observations may be included. These observations will be done with the least amount of interruption as possible, as to limit disruption and allow class to be as it would be normally. Video tapes could be made of these sessions for later review.

C. Confidentiality:

Your son/daughter's name will in no way be used in connection with the research or publications derived from the research The interviews will be coded S1, S2, S3, ...etc. to match audio data with that of the interview protocol. The audio tapes and the interview protocol along with any other documentation involved in the study will be locked and stored at the residence of the principle interviewer. Once the research is completed all audio recordings will be destroyed.

D. Subject Benefit/Risk:

There are no foreseeable risks or benefits beyond those present in normal everyday life and those that may occur by participating in a study that may help others. Because of the confidentiality of the research project there is near zero risk for the participants.

Interview Protocol

Research Project:

Time: Date:

Place:

Interviewer: William J. Arbuckle

Interviewee:

Position of Interviewee: Describe educational background and any significant events that were/are influenced by the Cognitive Tutor Algebra 1 classroom they are experiencing.

Questions:

1. What benefits did you encounter as a result of the Cognitive Tutor Algebra 1 classroom experience?

2. What drawbacks did you encounter as a result of the Cognitive Tutor Algebra 1 classroom experience?

3. How did the Cognitive Tutor Algebra 1 classroom experience effect your attitude toward school?

4. How did the Cognitive Tutor Algebra 1 classroom experience effect your attitude toward mathematics?

5. What effect did the Cognitive Tutor Algebra 1 classroom experience have on the relationships formed over the year?

6. Was this the only Computer Aided Instruction classroom experience you have ever encountered?

7. What was your initial feeling once you realized you were in this new class?

8. How would you describe this experience to a friend?

9. Prior to this experience what was mathematics to you and how has that changed because of this class?

10. If you were to be asked to draw a picture of what mathematics is what would you draw?

APPENDIX D

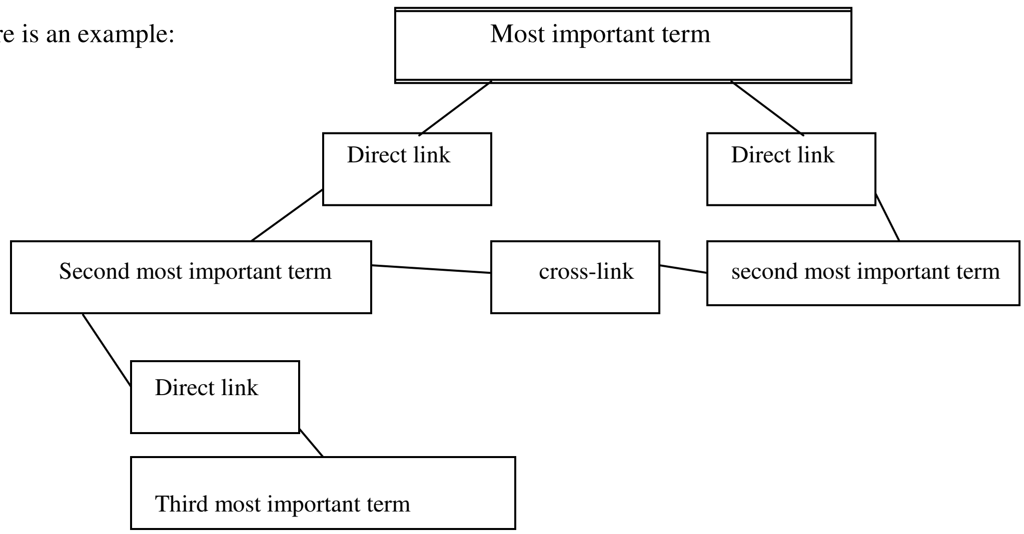
Concept map instructions.

Today's date: _______________ Gender: _____ Initials: __________ FR SO JR SR

Please read the directions carefully

1. Use the terms below to make the concept map.
2. Place the terms on your map so that the most important terms are at the top, the next most important terms below, and so on.
3. Draw boxes around the terms, and lines connecting the boxes.
4. Please, label all the lines.
5. At any connecting lines, you think of which show links between terms and please label all cross-link lines.

Here is an example:



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This is a list of terms to start your map.

* Polynomial	* Graphing	* Area	* Quadratic Formula
* Triangles	* Exponents	* Subtraction	* Addition
* Multiplication	* Division	* Variables	* Factors
* Algebra	* Geometry	* Factoring	* GCF
* LCM	*Degree	* Formulas	* Prime
* Absolute Value	* Integers	* Squares	* Pythagorean Theorem

You may add any terms you feel need to be.

APPENDIX E

Hello.

I am Bill Arbuckle and I teach at North High School here in Edmond. I am finishing my research for my PhD at OU, and as part of the requirements for that degree, I am looking at the understanding of math concepts and the change that take place while using Cognitive Tutor when compared with a traditionally taught class. I am very excited to hear what you have to say and see how things develop.

First, we need to know what this will mean for you. I need to meet with about twelve of Mr. Gowen's students once to twice a week for about 30 minutes to an hour through the end of the semester. This will in no way interfere with your classes or be a burden on you. In addition, participation in this study will not affect your grade in any way so you can be open and honest with no fear.

I am hoping that everyone that I am contacting with this letter is on a schedule of either 1-6 or 1-7. If this is not the case, please contact me telling me your schedule.

I also would like us to meet some time this week maybe before school in the Library and get things started. I am looking at Tuesday or Wednesday at 7:15 am. Does that work for you? We do not need to meet as a big group but we can, and we can meet individually also.

Please let me know if you can still help me in the study by getting back with me as soon as possible. I will need a way of getting a hold of you like an email address you check or phone number.

You will also find enclosed a permission slip for your parents to sign and a consent form for you to sign. For you to participate I must have these signed. Please have these when we meet this week.

I look forward to hearing from you. My contact info is down below.
Please complete the enclosed survey/questionnaire also.

Thanks again,

Bill Arbuckle Home # 478-7037 and Cell # 229-3935

PS – My email addresses are:
Work email: william_arbuckle@edmond.k12.ok.us
Home Email: mrbill@the5arbuckles.com

Please use both when emailing therefore
I can get them at school and at home.

THANKS ONCE AGAIN!!!

APPENDIX F

Name: ____________________________

Hour:____ Schedule:_1-7__2-7__1-6_

School Yr.: FR SO JR SR

1. What benefits/drawbacks have you encountered as a result of the Cognitive Tutor Algebra 1 classroom experience?

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2. How did the Cognitive Tutor Algebra 1 classroom experience effect your attitude toward school?

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3. What was your initial feeling once you realized you were in this new class?

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____
____

4. How would you describe this experience to a friend?

____
____
____
____

5. How have you done in math? What kind of math student are you?
   Poor Below Avg. Average Above Avg. Excellent

6. Would you be willing to participate in a study over Cognitive Tutor? In saying yes, you are not committing to anything but may be contacted about possible participation.

YES or NO

Name: ________________________

Hour:____ Schedule:_1-7__2-7__1-6_

School Yr.: FR SO JR SR

After reading the enclosed letter, please answer these:

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1. How have you done in math?
What kind of math student are you?

<u>Poor</u> <u>Below Avg.</u> <u>Average</u> <u>Above Avg.</u> <u>Excellent</u>

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2. Have most of your math teachers been good or bad math teachers?

GOOD or BAD

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3. Would you say that math is your favorite subject?

YES or NO

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4. Would you be willing to participate in a study over Algebra 1? In saying yes, you are not committing to anything but may be contacted about possible participation.

YES or NO?

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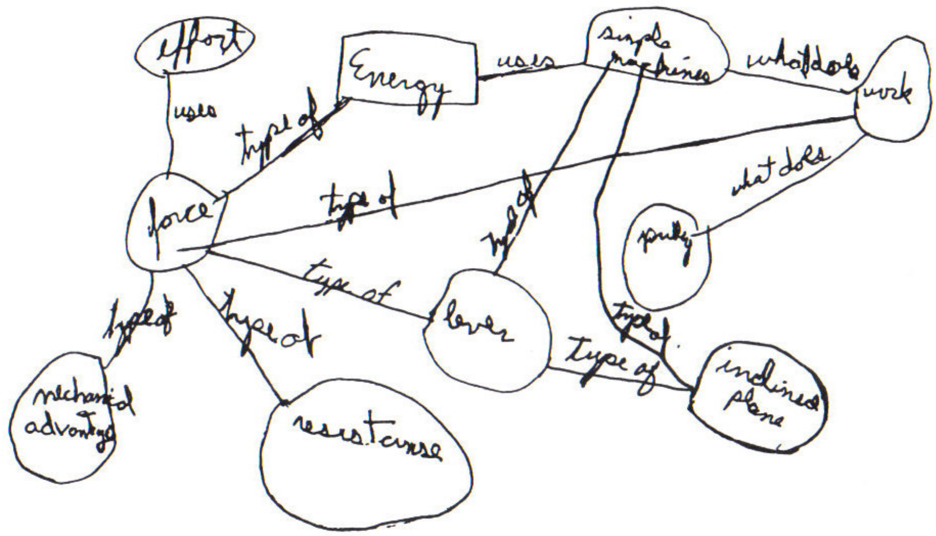
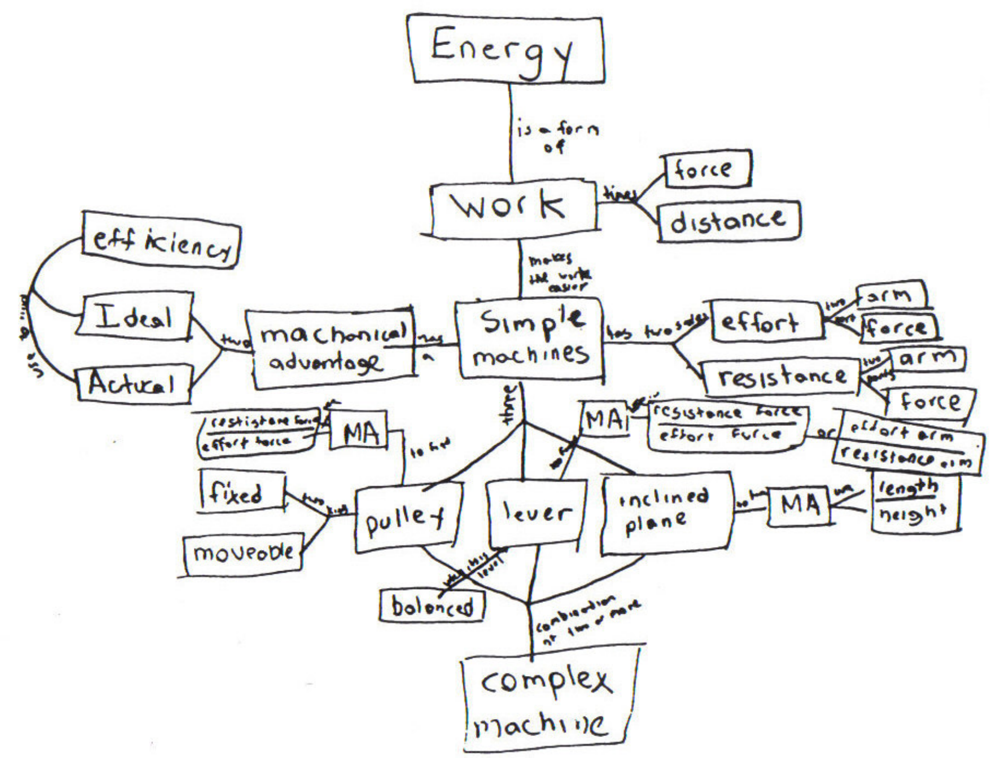
APPENDIX G



effort
uses
Energy
uses
simple machines
what does
work
type of
force
type of
type of
what does
pully
type of
lever
type of
type of
type of
type of
inclined plane
mechanical advantage
resistance



Energy
is a form of
work
times
force
distance
makes the work easier
efficiency
Ideal
Actual
machanical advantage
two
has a
Simple machines
has two sides
effort
arm
force
resistance
arm
force
three
MA
resistance force
effort force
MA
resistance force
effort force
or
effort arm
resistance arm
fixed
moveable
pulley
lever
inclined plane
MA
length
height
balanced
combination of two or more
complex machine

APPENDIX H

Name: ______________________

Date: __________ ***Hour:*** ______

<u>How Do These Relate?</u>

<u>Instructions:</u>
You may use the items included in your kit to help you in explaining below how all the words listed in the word-bank relate to each other.

<u>Included Materials:</u> Blank cards, Word Cards, & String

<u>Word-bank:</u>

Effort	Energy	Force
Inclined Plane	Mechanical Advantage	Pulley
Lever	Resistance	Work
	Simple Machines	

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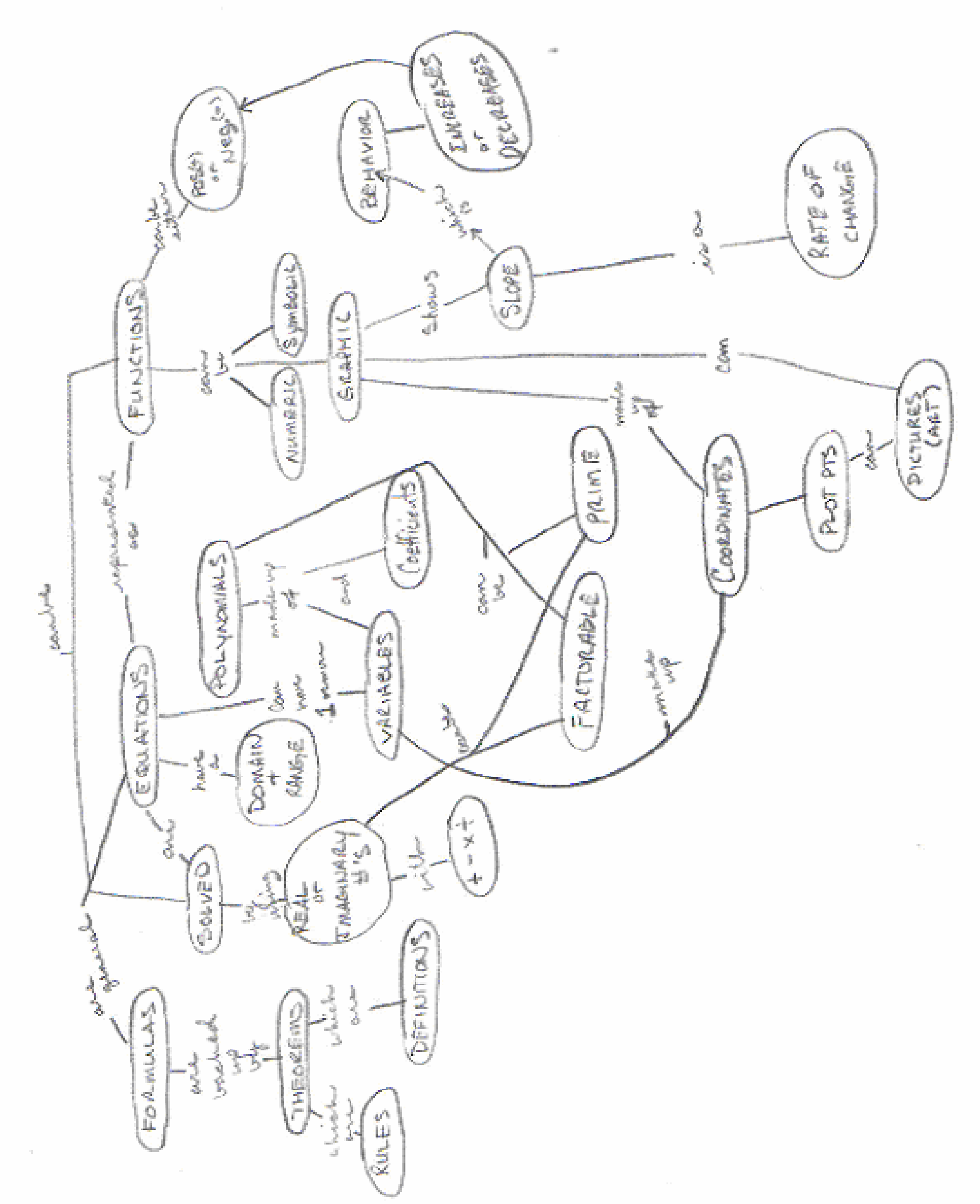
APPENDIX I

Our Expert Map



APPENDIX J

Rationals Pre-Test

Page 1 Form 1

CIRCLE THE LETTER OF THE BEST ANSWER!
Turn in all scratch paper when complete.

1. Simplify: $\frac{-x}{x - x^2}$

   A) $\frac{1}{x + 1}$ B) $\frac{-1}{x - 1}$ C) $\frac{-1}{x + 1}$ D) $\frac{1}{x - 1}$

2. State the excluded values of x for $\frac{x^2 + 9x + 20}{x^2 - 14x + 45}$.

   A) $x \neq 5$ or 4 B) $x \neq -9$ or -5 C) $x \neq 9$ or 5 D) $x \neq -5$ or -4

3. Multiply: $\frac{x - 4}{3x - 4y} \cdot \frac{9x^2 - 16y^2}{2x^2 - 13x + 20}$

   A) $\frac{3x + 4y}{2x - 5}$ B) $\frac{3x^2 + 4y^2}{2x - 5}$ C) $\frac{3x - 4y}{-3x - 13}$ D) $\frac{3 + 4y}{-3}$

4. Find the quotient in lowest terms: $\frac{u^5x}{y} \div \frac{ux^4}{y^3}$

   A) $\frac{x^3}{u^4y^2}$ B) $\frac{u^5xy + ux^4}{y^3}$ C) $\frac{u^4y^2}{x^3}$ D) $\frac{u^6x^5}{y^4}$

5. Divide: $\frac{x^2 + 4x - 7}{x}$

   A) $x - 3$ B) $x + 4$ C) $x + 4 - \frac{7}{x}$ D) $x^2 + 4x - \frac{7}{x}$

6. Divide: $\frac{-3x^3 - 3x - 9}{x - 2}$

   A) $-3x^2 - 9x - 18 - \frac{45}{x - 2}$ B) $-3x^2 - 6x + 9 + \frac{9}{x - 2}$

   C) $-3x^2 - 9x - 27 - \frac{54}{x - 2}$ D) $-3x^2 - 6x - 15 - \frac{39}{x - 2}$

7. Subtract: $\frac{-4x - 4}{x^2 - 81} - \frac{-5x - 13}{x^2 - 81}$

   A) $-\frac{1}{x + 9}$ B) $\frac{1}{x - 9}$ C) $\frac{x - 17}{x^2 - 81}$ D) $\frac{1}{x + 9}$

8. Add: $\dfrac{x + 2}{x^2 + x - 12} + \dfrac{x - 5}{x^2 - 16}$

A) $\dfrac{2x^2 - 2x + 7}{(x + 4)(x - 4)(x - 3)}$ B) $\dfrac{2x^2 - 2x + 23}{(x + 4)(x - 4)(x - 3)}$

C) $\dfrac{2x^2 - 10x + 23}{(x + 4)(x - 4)(x - 3)}$ D) $\dfrac{2x^2 - 10x + 7}{(x + 4)(x - 4)(x - 3)}$

9. Write as a single fraction in lowest terms: $\dfrac{g - \frac{4}{f}}{g^2 + \frac{1}{f^2}}$

A) $\dfrac{f^2g - 4f}{f^2g^2 + 1}$ B) $\dfrac{f^2g^2 + 1}{f^2g - 4f}$ C) $\dfrac{f^2g - 4}{f^2g^2 + f}$ D) $\dfrac{f^2(g - 4)}{f^2g^2 + 1}$

10. Solve for x: $\dfrac{x}{x + 17} - \dfrac{1}{18} = \dfrac{-17}{x + 17}$

A) no solution B) 17 C) -17 D) 0

APPENDIX K

Rationals Post-Test

Page 1 Form 1

Mark the Scan-Tron with best answer.
Turn in all scratch paper when complete.

1. Simplify: $\frac{-x}{x - x^2}$

   A) $\frac{-1}{x - 1}$ B) $\frac{1}{x - 1}$ C) $\frac{-1}{x + 1}$ D) $\frac{1}{x + 1}$

2. State the excluded values of x for $\frac{x^2 + 9x + 20}{x^2 - 14x + 45}$.

   A) $x \neq -9$ or -5 B) $x \neq -5$ or -4 C) $x \neq 9$ or 5 D) $x \neq 5$ or 4

3. Multiply: $\frac{x - 4}{3x - 4y} \cdot \frac{9x^2 - 16y^2}{2x^2 - 13x + 20}$

   A) $\frac{3x + 4y}{2x - 5}$ B) $\frac{3 + 4y}{-3}$ C) $\frac{3x^2 + 4y^2}{2x - 5}$ D) $\frac{3x - 4y}{-3x - 13}$

4. Find the quotient in lowest terms: $\frac{u^5x}{y} \div \frac{ux^4}{y^3}$

   A) $\frac{u^4y^2}{x^3}$ B) $\frac{u^6x^5}{y^4}$ C) $\frac{u^5xy + ux^4}{y^3}$ D) $\frac{x^3}{u^4y^2}$

5. Divide: $\frac{x^2 + 4x - 7}{x}$

   A) $x + 4$ B) $x^2 + 4x - \frac{7}{x}$ C) $x - 3$ D) $x + 4 - \frac{7}{x}$

6. Divide: $\frac{-3x^3 - 3x - 9}{x - 2}$

   A) $-3x^2 - 9x - 18 - \frac{45}{x - 2}$ B) $-3x^2 - 6x - 15 - \frac{39}{x - 2}$

   C) $-3x^2 - 9x - 27 - \frac{54}{x - 2}$ D) $-3x^2 - 6x + 9 + \frac{9}{x - 2}$

7. Subtract: $\frac{-4x - 4}{x^2 - 81} - \frac{-5x - 13}{x^2 - 81}$

   A) $\frac{x - 17}{x^2 - 81}$ B) $-\frac{1}{x + 9}$ C) $\frac{1}{x + 9}$ D) $\frac{1}{x - 9}$

8. Add: $\dfrac{x + 2}{x^2 + x - 12} + \dfrac{x - 5}{x^2 - 16}$

A) $\dfrac{2x^2 - 10x + 7}{(x + 4)(x - 4)(x - 3)}$ B) $\dfrac{2x^2 - 2x + 7}{(x + 4)(x - 4)(x - 3)}$

C) $\dfrac{2x^2 - 10x + 23}{(x + 4)(x - 4)(x - 3)}$ D) $\dfrac{2x^2 - 2x + 23}{(x + 4)(x - 4)(x - 3)}$

9. Write as a single fraction in lowest terms: $\dfrac{g - \frac{4}{f}}{g^2 + \frac{1}{f^2}}$

A) $\dfrac{f^2g - 4}{f^2g^2 + f}$ B) $\dfrac{f^2g^2 + 1}{f^2g - 4f}$ C) $\dfrac{f^2g - 4f}{f^2g^2 + 1}$ D) $\dfrac{f^2(g - 4)}{f^2g^2 + 1}$

10. Solve for x: $\dfrac{x}{x + 17} - \dfrac{1}{18} = \dfrac{-17}{x + 17}$

A) 0 B) no solution C) 17 D) -17