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A Tutor Design For Multicolumn Addition In Elementary Education

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A TUTOR DESIGN FOR MULTICOLUMN ADDITION IN ELEMENTARY EDUCATION

by

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DEDICATION

This thesis is dedicated to my advisor who committed himself beyond reason in encouraging me to complete the research and the paper. It is also dedicated to my wife whose patience and long-suffering allowed me the grace I needed to complete my graduate work.

BIOGRAPHICAL SKETCH

Moise Burgess was born on October 18, 1954, in Sumter, South Carolina. He received the Bachelor of Science degree in Computer Engineering from Worcester Polytechnic Institute in 1978. He is a candidate for the Master of Science degree in Computer Science.

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ABSTRACT

Burgess, Moise. A TUTOR DESIGN FOR MULTICOLUMN ADDITION IN ELEMENTARY EDUCATION**. (Major Professor: Dr. Albert C. Esterline)**, North Carolina Agricultural and Technical State University.

Individual tutoring provides a substantial improvement over traditional classroom instruction. Researchers in tutoring and tutoring systems have approached the study of why tutoring is effective and came to varying conclusions. Both quantitative and qualitative research was performed. The quantitative research addresses the questions: would students use the tools of student construction to help solve problems, and would a tutor designed using elements from tutoring theory allow students to solve multicolumn addition problems without assistance. The tutor was designed to scaffold for student construction, help students resolve impasses, provide positive and negative feedback, and use a five step dialog frame. Cognitive modeling used production from ACT-R theory.

Quantitative research has not been able to definitively answer the question of what makes tutoring effective. Qualitative research was used in an attempt to generate a hypothesis regarding effective tutoring rather that testing one. The qualitative method used was focus groups. The tutor developed was used as a pre-cursor to the focus group discussion. The focus group was used to get qualitative data on what student's thought was effective in a tutor. The students were able to successfully use the tutor to solve multicolumn addition problems. The qualitative research process generated a hypothesis about tutoring effectiveness.

CHAPTER 1

Introduction

The current most widely used method of instruction has the instructor standing in front of the classroom giving verbal instructions and lessons to the students and the students taking notes or trying to remember what is being said. It is true that there have been enhancements such as better textbooks and computers, but the fundamentals have remained the same for hundreds if not thousands of years. What makes this situation even worse is that most educators now recognize that there are “multiple intelligences” (Armstrong, 2009). Students have varied talents, skill and abilities; and different ways of learning. Special classes in the arts, sciences, and other areas only partially address these problems. In reality, no two students are exactly alike. If we wished to develop the best instructional method for a particular student, it would require knowing that student’s profile of strengths and weaknesses and developing instruction precisely based on this profile. However, optimizing instruction for one student would probably leave another at a disadvantage.

Children graduate from high school unprepared to do college level work because they have not been taught the basics. Topics in arithmetic should be mastered in elementary grades. If they are not, this absence of knowledge will handicap a student in many other math subjects. The dilemma here is that we usually have only one teacher and between 15 and 30 students. Even if the teacher were willing to try to teach each student according to the student’s distinct needs, it would be impossible for one teacher to customize instruction, sometimes in several different subject areas, for a whole class of students. Also, many teachers are frustrated by having to slow down or constantly repeat information for students who are poor learners in a particular subject area. What is needed are helpers for the teacher, assistants who can give individual, specialized attention to a specific student in a particular subject and adapt instruction to the individual needs of that student. Computerized tutoring systems seek to fill this need.

The purpose of teaching is for the students to learn. Yet, in his book on multiple intelligences (MI), Armstrong states that

> "... MI theory suggests that no one set of teaching strategies will work best for all students at all times. All children have different proclivities in the eight intelligences, so any particular strategy is likely to be highly successful with one group of students and less successful with other groups." (Armstrong, 2009).

There are different tutoring strategies. One method is a continual evaluation where the student can be corrected immediately if they have a misconception. Keeping students on the correct solution path is a common part of tutoring (VanLehn et al. 2003).

Modern tutor systems should be able to deal with the logic of solving the immediate problem but should also be capable of *meta-level* reasoning about the problem to be solved (Wenger, 1987). This means that systems must be capable of learning. The student's methods and results are monitored, and the student is evaluated. The results are used to alter both the student model and the instructional model (Ong et al. 2009). The student model is a computer representation of what the student knows and the student's misconceptions. The instructional model contains the pedagogical strategies adapted to teach a particular student. The flexibility of this approach will depend on how accurately the computer tutor is able to adapt to the behavior of the student.

The goal was to design a computer-based tutor that interacts with a student in a manner similar to that of a human tutor using the theory of cognitive modeling called ACT-R (Anderson 1996). What was attempted is a tutor that will use production rules, constraints, and hint dialog, implement the five step dialog frame, and use commonly agreed upon learning strategies. The focus was on developing a tutor that can communicate with the student in a manner similar to that of a human tutor.

There is no attempt to analyze how a student thinks, but the effort is intended to remediate incorrect problem solving behavior. An analogy is to driving a car. You do not have to know how automobiles work internally. Visual feedback and the feel of the road provide enough information for the driver to keep the car on the road. One theory of how humans solve problems is by learning production rules (Anderson 1996). The goal and sub-goals of production rules were used to provide the context for creating the dialog. The dialog simulates how a human tutor would communicate with a student. The problem solving steps and tutor dialog were recorded and the results evaluated. The expert model provided the correct production rules needed to evaluate the student's responses. The buggy rules were not implemented in this phase of the research. The tutor's dialog provides the guidance to the student in solving the problem. The expected result was that student performance would improve when the tutor is designed following these principles.

Elementary learning is important because, if certain skills are not learned during the early years, they could handicap learners into adulthood. Much of advanced tutor development skips elementary topics as too simple. However, hundreds of computer-based tutors are needed for topics in elementary education. This tutor development with its focus on ACT-R, constraints, dialog, elementary arithmetic, and a results-based approach are a combination of elements that could represent a simplifying approach to tutor design.

Developing a tutoring system requires an understanding of teaching and learning. The methods involved, whether considered an art or science, will guide the developer in the correct approach to thinking about a system that can solve the problems identified by the pedagogy of a particular area. The development process also requires models of how the system will behave. The model is broken down to the component level. Historically, the model involved components for the expert, the learner and the instructor. Eventually, the importance of the interface that communicates with the learner was recognized for its importance (Ong et al. 2009). . The proposed design implements the model but is required to consider a greater level of detail, including how to implement the theoretical model in a real world environment. Different choices can be made based on how the tutor wants or needs to interact with the learner. Cognitive models focus on the problem solving process in humans. Conversational tutors focus on Socratic dialog to interact and teach.

The flexibility and variety of interaction between tutor and learner will depend on the continued evolution of interface technology. Using voice, gestures, hand movement, facial expressions, and even sub-vocalized thoughts are already the subject of research projects (Shneiderman, et al. 2010). Not all of these are available as front ends to tutors today, but the graphical user interfaces, web interfaces and mouse controlled systems of today will evolve into a more interactive approach tomorrow.

Intelligent tutoring systems contain pedagogical knowledge, tutoring system components, and the communications interface between the tutor and the students. Each of these are addressed in detail in the next chapters and in Appendix B. Appendix A details the focus group guide developed initially to guide the focus group research.

In the following chapters all the elements of the research performed will be discussed. Chapter 2 discussed the pedagogical knowledge considered during the research. Chapter 3 explains the tutoring theories used in the design of the tutor. Chapter 4 details the considerations that went into the design of the tutor and the interface. Chapter 5 presents the theories and practices of qualitative research. Chapter 6 contains the results of both the quantitative and qualitative research. Chapter 7 gives the conclusion drawn from the research conducted.

CHAPTER 2

Pedagogy

An integral part of an intelligent tutoring system is incorporating knowledge about teaching. This requires a conceptual model of how the learner manipulates information and even the faulty thinking that leads to mistakes. We have a learning problem because we know what it takes for students to learn best but we do not have the resources to implement it. We are also able to model the student's cognitive behavior, including their misconceptions.

2.1. The Learning Problem

In 1984, Benjamin Bloom defined the "two-sigma problem," which states that students who receive one-on-one instruction perform two standard deviations better than students who receive traditional classroom instruction" (Bloom, 1984). In evaluating cognitive tutors, Anderson et al. (1995) stated that, in the best case, students achieve the same as in conventional schools in one-third the time. Adding a web-based interface to traditional classroom instruction does not provide any improvement over classroom instruction; in fact, it can be much worse for students who are undisciplined or who need special attention. A computer can never replace a good teacher. A good teacher develops a relationship with the student based on mutual respect whereby the student is motivated to achieve at their highest potential. However, when it comes to problem solving where students make mechanical or conceptual errors, intelligent tutoring systems may provide many of the benefits of individual instruction.

The expert advice on tutor design is as follows (Anderson et al. 1995).

- The best tutor designs are the ones that provide immediate feedback.
- The tutors work better if they are presented as non-human tools rather than emulating humans.
- The computer should have a computational model that solves the problem in the same way that the student is expected to solve the problem.

2.2. Cognitive Modeling

(Anderson et al. 1995) discussed a systematic way for developing and deploying tutors.

- Select a problem solving interface.
- Construct a curriculum under the guidance of a domain expert.
- Design a cognitive model for solving the problem.
- Build instructions around the productions in the models.

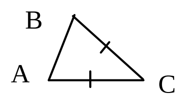
The ACT-R theory (Anderson 1996) is a theory of cognition which proposes that complex cognition is the result of the interaction of declarative and procedural knowledge. It states that declarative knowledge (facts, theorems) is goal independent. It can be acquired from observation and instructions. Procedural knowledge is the ability to use declarative knowledge to solve a problem. Cognitive skills depend on using declarative knowledge in a procedural context such as converting the knowledge into production rules. Problem solving behavior occurs when declarative knowledge is related to task goals. Knowledge compilation converts interpretive problem solving into production rules.

> “The fundamental assumption of ACT-R is that cognitive skills are realized by production rules. In order to support students to learn a specific task, that is, to learn a specific set of production rules that will enable students to perform the tasks correctly, cognitive tutors teach the underlying production rules.“ (Anderson et al. 1995)

Procedural knowledge is represented in the form of production rules. Figure 2.1 gives an example of a production for computing one of the angles in an isosceles triangle. When the tutor is successful in transferring knowledge from the expert to the student, the student’s use of production rules are optimized and the student becomes an expert. The student uses the most efficient production rules to solve the problem.

The following approaches are options for implementing cognitive tutors: Model tracing produces and uses a generic student model and follows the student’s progress against the model. Knowledge tracing, in contrast, produces and uses a student-specific model with customized problems (Mitrovic, et al. 2003). Model tracing uses a cognitive model to check whether or not the student is performing correctly by comparing each of the student’s steps with other correct or incorrect steps that are generated by the production system. To produce this cognitive model, one analyzes how humans solve problems in a particular domain and represents it in the form of production rules. The benefits of developing tutors using this model are as follows:

1) Cognitive tutors generate immediate feedback.
    a) They react to each step the student makes while solving a problem.
2) An error is detected when either a student response does not match any rule or does match a *buggy rule,* which represents anticipated mistakes.



Angle A is 65.
What is angle C?

Two correct production rules:
IF goal is to find an angle in an isosceles triangle ABC and AC = BC and angle A is known THEN set the value of angle B to A.

IF goal is to find an angle in a triangle ABC and angles A and B are known, THEN set the value of C to 180-A-B

Buggy production rule:
IF goal is to find an angle in an isosceles triangle ABC and angle A and C are at the bottom of the triangle and angle A is known THEN set the value of angle C to A.

Figure 2.1 - Three production rules for computing the size of an angle (Mitrovic, et al. 2003)

2.3. Learner Misconceptions

Consider the example in Figure 2.2 (Ong et al. 2009) of a possible arithmetic tutoring system. Suppose that three learners are given two addition problems that they answer as illustrated in Table 2.2. All three participants answered incorrectly; however, they have different underlying misconceptions that caused them to err in different ways.

- Student A fails to carry.
- Student B always carries (sometimes unnecessarily).
- Student C has trouble with single-digit addition.

An intelligent tutor should be able to detect and remedy any of these learning misconceptions in the student.

Student A	22 +39 51	46 +37 73
Student B	22 +39 161	46 +37 183
Student C	22 +39 62	46 +37 85

Figure 2.2 – Student Model Misconception

CHAPTER 3

Tutoring Theory

Intelligent tutoring systems have been under discussion for nearly half a century. However, only recently has all the hardware and software come together to make it possible for practical development to commence. The development of animated, high resolution, graphical user interfaces has made it possible to create natural interfaces that use direct manipulation, voice synthesis and recognition, and inexpensive artificial intelligence methods to create an interactive environment that can, in some cases, replace human tutors. Although there is not one consistent view of intelligent tutoring systems, there is a typical model used to guide the design. This typical model includes components for the student, instructor and the expert. They are also based on modern user interface technology.

Early systems such as SOPHIE were text-based systems that used text screens and keyboards to communicate with the user (Wenger, 1987). Even today, systems such as GnuTutor (Olney, 2009) use keyboard input. This is due to the dual problems of speaker independent speech recognition and accurate natural language understanding. Solving both of the problems at the same time has presented an impossible obstacle for all but the simplest systems. Cognitive tutors are the real workhorses of intelligent tutoring systems today. The authoring programs make developing tutors, based on the ACT-R theory and concepts, a science and not and art. Inductive logic programming (ILP) (Flach, P. 1994) offers the greatest improvement long term because of its ability to synthesize rules from facts. It is able to represent the knowledge required for cognitive tutors and create new rules from facts.

3.1. Theoretical Foundations of Effective Tutoring

The reason tutoring is effective may be related to dialog, the pedagogical strategy, the environment, and the internal motivation of the student. There is no consensus on why it is effective. However, we know from research and experience that tutoring is effective and provides benefits beyond traditional classroom instruction. In order to satisfy the needs of elementary education topics, hundreds of tutors are needed. If we are to satisfy this need, we will need a way to create tutors that are simple, flexible, and can be created quickly. Human tutors may have subject matter knowledge but no training as tutors. They may also be skilled tutors with subject matter knowledge and training, or experts who have mastered the subject matter and achieved highly successful tutoring results. Computer-based tutors may be simple drill and practice tutors that only indicate correct or incorrect results, intelligent tutors that adapt their teaching strategies to individual students, or anything in between. Individual attention by tutors has been shown to dramatically improve student performance (Bloom, 1984). Tutoring systems that can replace humans in some circumstances will allow individual attention for many more students.

Four groups of researchers published on the topic of tutoring effectiveness. Chi et al. (2001) found that a key element of tutoring is student construction using scaffolding. VanLehn et al. (2003) found that coached problem solving during impasses was effective. Ohlsson et al. (2007) investigated computational models of tutoring effectiveness and proposed a new method based on multiple regression. Graesser et al. (1995) proposed that tutoring effectiveness is due to the natural interaction of unskilled tutors and tutoring dialog frames.

3.2. Student Construction Using Scaffolding

One important instructional difference between teachers and tutors is that tutors have the opportunity to pursue a given topic or problem with an individual student until the student has mastered it. Human tutoring skills involve the pedagogical skills of giving feedback, scaffolding, explaining, correcting errors, and knowing when to apply and when to hold back information to allow the student to find and fix the errors. There is a common notion that tutoring effectiveness is due to the correct and appropriate application of pedagogical skills, but this is not proven. Pedagogical skills may be necessary, but, since tutoring is similar to adult-child interaction, scaffolding may be the pivotal step in tutoring as well (Chi et al. 2001).

A typical tutoring dialogue consists of the five broad steps (Chi et al. 2001):

a. Tutor asks an initiating question.
b. Student provides a preliminary answer.
c. Tutor gives (confirmatory or negative) feedback on whether the answer is correct or not.
d. Tutor scaffolds to improve or elaborate the student's answer in a successive series of exchanges.
e. Tutor gauges student's understanding of the answer.

If one considers scaffolding to be any kind of guidance that is more than a positive or negative feedback, then scaffolding includes the following (Chi et al. 2001):

a. decompose a complex task into simpler ones,
b. do part of the task,
c. initiate a task and let the student do the rest,
d. remind the student of some aspect of the task,
e. and so forth.

Chi et al. (2001) researched the roles of the student's construction of knowledge in learning from tutoring as well as the effect of tutor-student interaction. Their results showed that students learned just as well without hearing tutor explanations and feedback. They also clearly showed that student construction from interaction is important for learning, suggesting that an ITS (intelligent tutoring system) ought to implement ways to elicit students' constructive responses. They proposed three possible benefits of these strategies (Chi et al 2001):

1. An interactive style seems to be more motivating, which can lead to a greater enjoyment of learning.
2. Tutors are more accurate in their assessment of students' understanding when they are prompting and scaffolding the students rather than giving explanations.
3. The students in the interactional style of tutoring transferred their knowledge better than the students in the didactic style of tutoring.

One way to elicit student construction is through scaffolding. However, implementing a scaffolding type of prompting in an ITS is complex because scaffolding requires an understanding of what the student uttered, whether it was locally correct, incorrect, or incomplete, or somehow globally flawed. Such understanding may be all that is needed to determine what kind of scaffolding prompts to give and when to give them because average tutors seem to be able to scaffold deeply in extended scaffolding episodes naturally without any training. Natural language understanding and an understanding of the content domain are crucial for appropriate scaffolding (Chi et al. 2001).

3.3. Coached Problem Solving During Impasses

According to (VanLehn et al. 2003), tutoring can be viewed as coached problem solving and coached problem solving can be viewed as a collaborative problem-solving effort. Most tutorial dialog focuses on steps in solving the problem. Also, most tutors keep students on a correct solution path. Finally, the structure of the problem-solving steps is what primarily determines the structure of the dialog. The tutor’s job is to ensure that the solution does not stray too far from the correct solution path. The tutorial dialog can be viewed as a sequence of learning opportunities. Each learning opportunity addresses one principle, and there may be more than one learning opportunity per principle. A principle can be learned by successfully applying the learning opportunities for that principle.

Work on cognitive skill acquisition without a tutor found that learning was often associated with impasses (VanLehn et al. 2003). An impasse occurs when a student realizes that he or she lacks understanding of how to solve a specific step in a problem. Another way of defining an impasse is that it occurs when a student gets stuck, detects an error, or does an action correctly but expresses uncertainty about it. Impasses appear to be strongly associated with learning. This suggests that tutors should encourage impasses (VanLehn et al. 2003). When an intelligent tutoring system gives a sequence of hints to a student, the first hint usually states a goal. Such goal-setting hints should be useful both because they insure that the student and the tutor are working on the same goal, and because the goal is a retrieval cue and a selection cue for the principle that the student should apply. Explanations may not be associated with most learning. "If that is true then we face the counterintuitive but intriguing possibility that the content of the tutor's comments may not matter much" (VanLehn et a.l 2003). The main effect of tutorial explanations may be to prompt students to think harder with the knowledge that they already possess. If so, then it does not matter what the tutors say or even whether the students understand it; the mere fact that the tutors are talking about a principle motivates the students to think harder about it. This would explain why individual explanation features often did not correlate with learning. Tutorial behavior that gets students to think, such as generating opportunities for impasses or giving zero-content prompts, may be the key to why tutoring is so effective (VanLehn et al. 2003).

VanLehn et al. (2003), suggest that an optimal tutoring strategy may be

a. to let the student reach an impasse,
b. to let prompt them to find the right step, and
c. to let prompt them to explain the step and provide an explanation only if they have tried and failed to provide their own.

Some intelligent tutoring systems approximate this tutoring strategy in that they always let students try to do a step before giving hints on it, and their hint sequences gradually increase in content. In the case where a tutorial explanation is necessary, explanations that were just deep enough to allow students to solve the problems were more effective than deeper explanations (VanLehn et al. 2003),

3.4. Computational Models of Tutoring Effectiveness

Ohlsson et al. (2007) discussed research into why tutoring is effective and investigated computational models of effective tutoring strategies. These models are considered essential components of dialogue interfaces to ITS implementations. Their finding was that the ITS community does not yet agree on a consistent set of effective tutoring strategies. Tutor-tutee interactions are so rich and complex that researchers have not yet converged on a shared set of tutoring moves. Nor has tutoring research converged on a widely agreed-upon theory of how the behavior of tutors should be segmented and characterized. Tutoring moves are the basic units of analysis. Segmentation and characterization are precursors to investigating which parts of tutoring produce the best gains. Their intent was to present an argument and two proposals: one to develop coding schemes that are better informed by theories of learning and a second to replace code-and-count methodology with one based on multiple regression. In their critique of code and count analysis, Ohlsson et al. (2007) stated that "[t]here is no guarantee that the moves that account for most of the variance in learning outcomes are necessarily the moves that occur most frequently. After all, the tutors themselves, even expert tutors, do not have a theory of tutoring" Ohlsson et al. (2007) s that human interactions are very complicated and shaped by multiple factors, including the surrounding culture and the rapport between a particular tutor and a particular student. Therefore, the most effective tutoring moves might be a few moves embedded inside a rich, varied, and complicated interaction that exists for a variety of reasons not directly related to learning outcomes (Ohlsson et al. 2007).

Even if no theory of skill acquisition is widely accepted, there is agreement among researchers that people learn in at least the following four ways.

a. People can learn by capturing and encoding successful steps during problem space search.
b. People can learn by detecting and correcting their errors.
c. People can learn by encoding declarative facts about the domain or about the types of problems or tasks they are practicing, delivered via discourse.
d. People can learn by compiling declarative representations of the tactics and strategies they are trying to learn into executable cognitive strategies.

These four types of learning suggest ways in which tutors can support learning.

a. A tutor can provide positive feedback to confirm that a correct but tentative student step is in fact correct.
b. A tutor can provide negative feedback that helps a student detect and correct an error.
c. A tutor can state the declarative information about the domain.
d. A tutor can tell the student how to perform the task.

It is highly likely that each tutor succeeds better with some students than with others. Success may be due to better rapport, more closely related and matching linguistic habits or thoughts, and so forth. It is therefore reasonable to focus on tutoring sessions, not tutoring persons. Most tutors do not spend much time trying to correct bugs and misconceptions. Intelligent tutoring systems that can recognize and repair bugs and misconceptions could provide improvements over normal tutors. The suggestion is that tutors provide gentle indirect feedback when correcting students. This is the approach taken by skilled tutors. Affective and motivational goals are important as well as cognitive ones. These include independent student learning ability and self confidence, challenging a student, giving the student a sense of control, and encouraging curiosity.

3.5. Natural Tutoring Effectiveness and Dialog Frames

Graesser et al. (1995), after researching tutoring effectiveness, stated that "the advantage may be attributed to conversational patterns of unskilled tutors rather than to esoteric pedagogical strategies of skilled tutors". The most visible elements of normal tutoring are collaborative problem solving, question answering, and explanatory reasoning in the context of specific examples. A five step dialog frame from his earlier work is as follows:

a. Tutor asks a question.
b. Student answers the question.
c. Tutor gives feedback on the students answer.
d. Tutor and student work together to improve the answer.
e. Tutor evaluates the student understanding.

Tutoring differs from classroom teaching in the following way. Classroom teaching typically follows a three-step pattern (Graesser et al 1995).

a. A teacher asks a question.

b. The student answers the question.

c. The teacher evaluates the student's response.

This may account for why tutoring is more effective than classroom teaching. The disadvantage of the five step dialog from is that it ignores the need for self-regulation, the processing of students detecting and correcting their own errors. Students may also become discouraged if given excessive negative feedback and correction. There is a need for a student to build self-confidence (Graesser et al. 1995).

None of the theories presented by the researchers in this section are universally accepted, but the principles they presented can be implemented for further research and practical application. In particular, simple methods of scaffolding for student construction, five-step dialog frames, coached problem solving at impasses, and context sensitive dialog are all elements that can be programmed and may contribute to better tutors.

3.6. Tutor Modeling

An important lesson was learned from the use of the Guidon tutoring system (Wenger, 1987), developed from the MYCIN expert system. The presentation of knowledge even from a good expert system is not sufficient to act as a tutor. Tutoring must include "logical and relational abstractions of knowledge". This knowledge about knowledge allows for flexible strategies in dealing with learning difficulties.

There have been improvements to the original systems mentioned above, and new authoring tools such as GnuTutor (0lney, 2009) and Cognitive Tutor (Koedinger, 2008) have become available for developers of tutoring systems. Current intelligent tutoring systems consist of four models (Ong et al 2009):

a. the expert model
b. the student model
c. the instructional model
d. the interface (communications) model

Expert Model

The expert model is an articulate (glass box) expert. This model is able to explain its own reasoning in solving problems and showing how it uses knowledge during tutoring.

Student Model

The student model generates facts relevant to the student's actions as well as facts that model the student's misconceptions. An attempt is made to record knowledge about student concepts, student misconceptions, and the student problem solving strategies.

Instructional Model

The instructional model makes meta-level decisions about how the lessons should be altered to benefit the student. An attempt is made to analyze the student's state and induce knowledge about the student's concepts, misconceptions, and problem-solving strategies. This induced knowledge is used to adapt to the student's learning pattern, interact in a dynamic manner with the student, and tailor instruction for the student.

Interface Model

The interface model depends on the status of the other models to determine what information to present to the student. It allows input and displays output appropriate to what is being taught.

3.7. Tutor Design

The following discussion addresses intelligent tutoring systems (ITS) and it summarizes material from (Ong et al. 2009). Traditional instructional methods present learners with facts and concepts followed by test questions. This method teaches them recall knowledge but not how to apply the knowledge they have learned. ITS systems, in contrast, can use active learning environments such as simulations and other highly interactive environments that require people to apply their knowledge and skills. In this way, students will retain and apply the knowledge more effectively when it is needed. ITS systems implement three types of knowledge, organized as separate software components. These implementations are of the models for the expert, student, and instructor.

The *expert model* represents subject matter expertise and provides the ITS with knowledge of what it is teaching. The expert model is the computer's representation of a domain expert's subject matter knowledge and problem-solving ability. This knowledge will be used by the instructor model to compare the learner's behavior to that of the expert model in order to determine what the learner does and does not know. Some ITS systems capture subject matter expertise in rules. Other systems embed the actual knowledge needed in the model. A *rule-based* system allows the tutoring system to generate problems on the fly then combine and apply rules to solve the problems. This approach is powerful but, in complex domains, it is difficult to provide comprehensive coverage of the subject matter. Complex problem generation is not a problem for elementary arithmetic. The *procedural system* embeds step-by-step procedures for accomplishing a task or solving a problem.

The *student model* represents what the user does and does not know and what skills the user does and does not have. This knowledge lets the ITS know about who it is teaching. The student model evaluates each learner's performance to determine their knowledge, perceptual abilities, and reasoning skills. Refer back to the examples of Figure 2.2. In these examples, the student supplies an answer to the problem, and the tutoring system captures the student's misconceptions from this answer. The misconception becomes a part of the student model. A tutoring system can also monitor a learner's sequence of actions to infer their understanding. This system can apply pattern-matching or production rules to detect sequences of actions that indicate whether the student does or does not understand.

The *instructor model* enables the ITS to know how to teach by encoding instructional strategies used via the tutoring system's user interface. The instructor model can refer to a detailed model of each user's strengths and weaknesses as compared to the expert model, and it can then provide highly specific, relevant feedback and instruction.

CHAPTER 4

Developing The Tutor

The tutor developed uses production rules, constraints, and guided dialog, and implements the five step dialog frame, and uses commonly agreed upon learning strategies. The tutor is designed to communicate with the student in a manner similar to that of a human tutor. Developing a tutor for multi-column addition is a test case for developing a wide range of tutors to help children in elementary and middle school who struggle because they need individual attention. A friendly interface was designed so that interface interaction would not hamper the student using the interface. Extending the design to other tutors will be considered. The components of a one-on-one tutoring system considered were as follows:

- The interface to the tutor
  - A way for the learner to enter data
  - Feedback on the learner's action
  - Information that helps the learner solve the problem
- The ability of the learner
  - Use of a computer keyboard to enter numbers
  - Use of a mouse to begin a new problem or ask for assistance
  - Background knowledge
  - Ability to understand the concept of multicolumn addition
- The background knowledge assumed for the learner is as follows:
  - Understanding of integer facts

- Learned addition concept
- Learned single-column arithmetic

4.1. Multicolumn Addition

In developing an intelligent tutoring program to teach multicolumn addition, some of the theory and principles of the ACT-R theory are used (Anderson 1996). Cognitive tutors are modeled on two kinds of knowledge, declarative and procedural. Declarative is represented as static memory structures called chunks. These chunks hold factual knowledge. Procedural knowledge is represented as production rules. The production rules are transformations that can lead to additional declarative knowledge. This is the process of learning.

Multicolumn addition can be taught as a series of mechanical operations or with an understanding of place-value arithmetic. Instead of column numbers, we could specify the columns as ones, tens, etc. However, this could introduce another level of complexity beyond teaching multicolumn addition as a mechanical process. Multicolumn addition could incorporate single column addition but this would complicate the process of students learning simple addition in a column. The tutor developed retains the simplest approach by teaching the mechanical process of performing multicolumn addition. The expected result of this development is to create an interesting tutor, not to fully implement ACT-R theory, but to create a tutor that collaborates with a student to help solve a problem. When a student solves a multicolumn addition problem in the manner discussed above, then these are the production rules the student will learn. The production rules are supplied by the expert module. In the examples that follow, T represents the top, B represents the bottom, n represents the column number from right to left, C represents the carry digit, and D represents the sum digit

Rule Set 1:

If either of the current addends or the current carry is not null, then the current sum of the non-null items can be computed as:

$$C_{n+1}D_n = \text{addend}T_n + \text{addend}B_n + \text{carry}_n$$

Rule Set 2:

If the current sum is greater than nine, then

Set C_{n+1} as Next Carry Digit

Set D_n as Current Sum Digit

Rule Set 3:

If the current sum is less than nine, then

C_{n+1} is NULL (no carry action)

Set D_n as Current Sum Digit

If the current addends and the current carry are null, then the answer is complete. The GOAL has been reached. The solution is defined by the weighted sum of the sum digits.

$$\text{Solution: } D_n 10^{n-1} \ldots + D_3 10^2 + D_2 10^1 + D_1 10^0$$

After the summation of a particular column, the expert model would store the activity as a Multicolumn Addition Chunk (fact) as in the following example.

Declarative Knowledge: The sum of 6 + 7 is 13

isa	sum
addend1	6

addend2	7
sum	13

4.2. Tutoring Interface

These are the characteristics of a tutoring system that must be understood when working with the tutor interface. There will be a separate goal for each column as well as an overall goal for the problem.

Skill to be acquired:	Perform Multicolumn Addition	
Goal:	Perform Column Addition	
Subgoal:	Find Sum	
Subgoal:	Write Sum Digit	
Subgoal:	Write Carry Digit	(if necessary)
Terminating Condition:	sumDigit=carryDigit=termDigits=empty/null/blank	

Figure 4.1 is the interface design for the multicolumn addition tutor. The tutor has a problem solving area for the student area and an information area for the developer to keep track of the current state of the system at all times.

The following are the capabilities of the tutoring interface.

- Generate a new problem.
- Calculate the solution and save it as the GOAL.
- Monitor the student's input.
- Calculate the sub-goal.
- Compare the expert's state to the student's state for the sub-goal.
- Provide hints or feedback to the student.

- Compare the student's latest answer to the GOAL.
- Stop when the GOAL is reached.

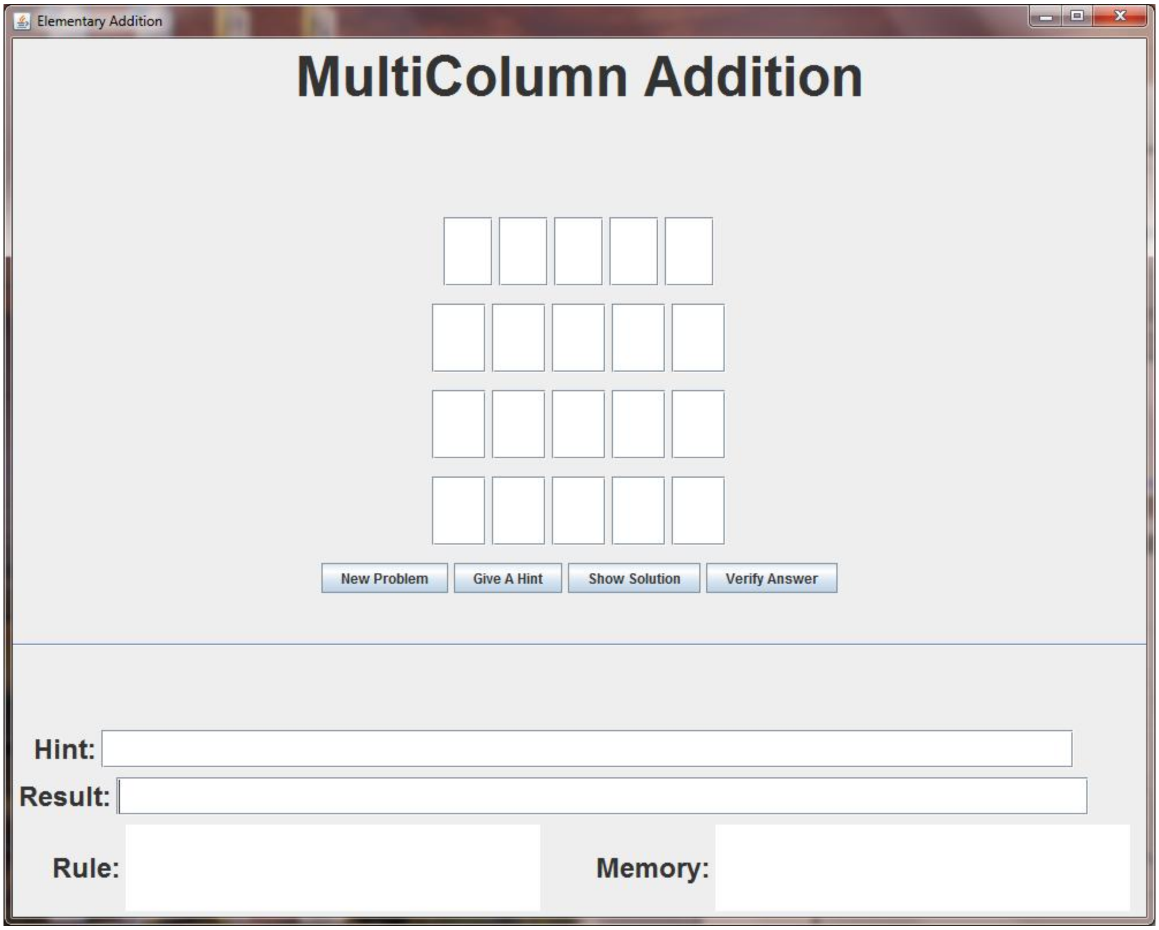


Figure 4.1 - Interface Design for Multicolumn Addition

4.3. The Tutoring Program

If a student makes a mistake, the tutor flags the mistake with the color red. If a student is performing a task incorrectly, the tutor is able to demonstrate the correct execution of the task. The tutoring program was not used to measure learning in this phase of the research. The focus of an intelligent tutoring system is the learner. The learner must have a degree of background knowledge to learn any new topic. The tutor attempts only to teach what is in the domain of discourse. Any other knowledge required will be assumed to be known by the learner. The learner is assumed to have the ability to perform single column addition as background knowledge. A single column addition problem is represented by the following:

Case 1	**Case 2**
5	**9**
4	**3**
--------	**---------**
9	**12**

In both cases, a production rule for calculating the sum can be represented by the following:

Sum = AddendT + AddendB **(T-Top, B-Bottom)**

The production rules for digit placement are not shown here. The learner is expected to understand place-value arithmetic and be able to correctly place single and double digit sums.

Multicolumn addition requires a repetitive set of steps to reach the goal. The learner must correctly complete the steps required to reach the goal. If we started with problems where all columns are in canonical form, each sub-goal would be equivalent to the goal for single column addition. The learner reaches the goal by completing the sub-goals as if completing a sequence of single-column arithmetic problems without any new knowledge being required.

5432
1234

6666

$$\mathbf{Sum_n = addendT_n + addendB_n}$$

The learner will encounter problems, however, when addition columns are in non-canonical form and the production rule above is used. The learner must start in the right column and work towards the left.

```
9876
2345
------
   11  (Error!)
```

When the learner takes this action, the tutor will compare the learner's response with the expert's and determine that the learner is taking an incorrect action for multi-column addition.

One method of preventing the student from making this error is by including a constraint.

$$\mathbf{Sum_n = addendT_n + addendBn \quad (if\ Sum_n < 10)} \text{ constraint}$$

This prevents the learner from making a mistake when a non-canonical form is encountered. However, the addition of the constraint does not tell the learner how to solve the problem. The tutor must teach the learner how to solve problems that may have carries.

A new production rule from the expert model is required. The tutor has to find a way to explain the use of this rule to the student. In multicolumn addition, only one digit at a time is written to the sum line even if there are two digits in the sum. Also, the placement of the carry digit must be considered. Rewriting the formula above to specify a single sum digit and a contingent carry digit gives the revised production rule.

$$\mathbf{D_n = addendT_n + addendB_n + carry_n \quad (if\ Sum_n < 10)}\ \text{constraint}$$

This rewrite does not change anything for columns in canonical form except add the possibility of a carry digit. The carry will always be zero for the first column. The following production rule will cover the cases where a particular column is in non-canonical form.

$$\mathbf{C_{n+1}D_n = addendT_n + addendB_n + carry_n \quad (if\ Sum_n >= 10)}\ \text{constraint}$$

The learner must be taught where to place the carry. Now the learner knows how to solve multicolumn addition problems for all sub-goals.

The last skill the learner must have is to determine when to stop computation. When the following condition exists, then the goal has been reached.

addendTn = addendBn = carryn = Empty/Null/Blank,

4.4. Tutoring Components

The expert model need only contain the knowledge that the student will be taught. It does not need to make available background knowledge that the student is expected to possess. The expert computes the sum of the current column and generates a chunk (fact) for the computed column sum. The following example is an illustration.

Declarative Knowledge: The sum of 6 + 7 is 1 3

isa	sum
addend1	6

addend2	7
currentCarry	0
nextCarry	1
sumDigit	3

The expert model also contains the production rules that would allow the sum to be calculated correctly and have the sum digit and carry placed correctly. This again is illustrated by an example.

Production Rules:

sum = 6 + 7 + 0

If sum < 10	sumdigit = sum	(where sum is of the form S)
If sum >= 10	sumDigit =S; nextCarry=C	(where sum is of the form CS)

Declarative Knowledge:

isa	sumdigit
S	Place the sum digit in the current column below the digits

Declarative Knowledge:

isa	carrydigit
C	Place the carry digit in the next column above the digits

The student computes the sum of the current column and generates a chunk for the computed column sum. Both of these are internal and are not displayed on the tutoring interface for the student. However, this information can be made visible to the researcher. When students learn multicolumn addition, their knowledge of single column addition is the starting point. When learning multicolumn addition, the student must be taught a new method of single column addition that is compatible with multicolumn addition. The next examples show the comparison of the difference between what the student knows about single-column addition and what they need to learn about multicolumn addition. This comparison is one means of learning.

Comparison Example

```
  6                          1
 +7                            6
 ---                   +       7
 13                           ---
                               3
```

Comparison Chunks

isa	additionFact	isa	multiColumnAdditionFact
addend1	6	addend1	6
addend2	7	addend2	7
sum	13	sumdigit	3
		nextCarry	1

They will also perform the same steps until they are able to do them correctly consistently. Repetition is another form of learning.

The purpose of the instructor model is to compare the student model to the expert model. When the two models are the same for a particular domain, then the instructor's task is complete. The first visible interaction is the motor action of the student on the interface: The student places the sum and the carry digit. The student's actions are evaluated for correct interaction and compared to the expert chunk and productions. The instructor will attempt to figure out the student's misconceptions based on the student's actions. The following are possible bugs in the student model.

Wrong sum digit

Wrong carry

Reversed sum digit and carry

No sum digit

No carry when carry exists

Incomplete operations

Carry when no carry exists

Some of the dialog with the student will be based on the information that is currently in working memory. Some candidate messages for tutor communication are as follows:

The sum is equal to the bottom digit plus the top digit plus the carry.

The sum is greater than or equal to 10.

The sum is less than 10.

The carry digit C must be placed above the digits in the next column.

The sum digit S must be placed below the digits in the current column.

Please begin adding the numbers.

The problem has been completed successfully.

An incorrect sum digit will indicate an improperly calculated sum or switched sum and carry digits. When the student gets an answer wrong, the mechanism for teaching that student the correct method will be the messages based on constraint violations and buggy rules. The buggy rules were not developed for this phase of the research.

4.5. Tutoring Interaction

In Figure 4.2, a sample multicolumn addition problem shows working memory, which contains the current state of the system. The interface also shows elements from the expert model and the student model. The instructor model manages the interface. It presents the problem interface and provides feedback to the student. It also manages the step-by-step interaction with the student and determines when errors are made, what messages to send to the student, and when the goal has been achieved.

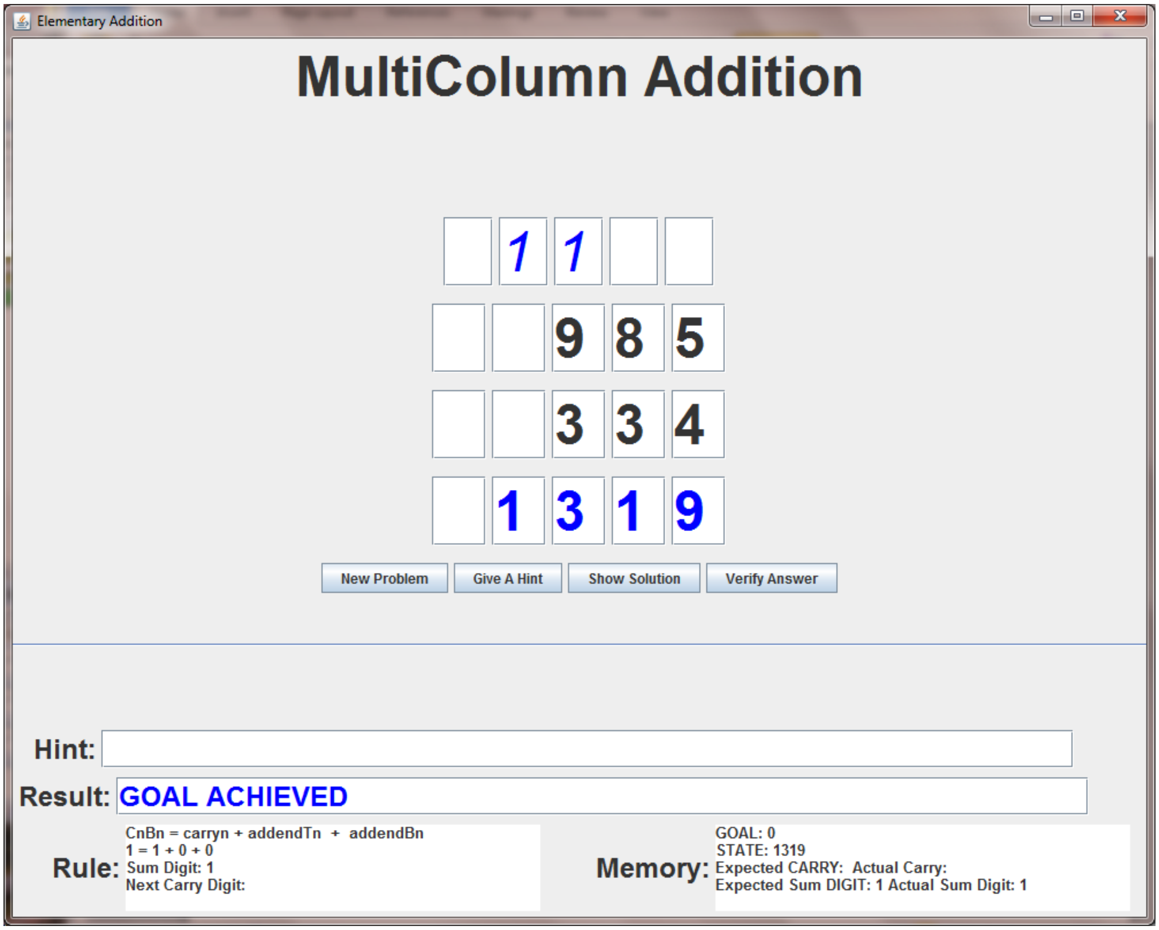


Figure 4.2 - Sample Multicolumn Addition Problem

CHAPTER 5

Focus Group Research

The focus group technique is a tool for studying ideas in a group context (Morgan 1988). Focus groups are a form of group interviews where the ideal form is the interaction of participants based on a given topic. "The hallmark of focus groups is the explicit use of the group interaction to produce data and insights that would be less accessible without the interaction found in a group (Morgan 1988)." Focus groups are defined as qualitative research and can be used as a self-contained means of collecting data or as a supplement to other qualitative or quantitative methods.

In addition to focus groups, the principle means of collecting qualitative data in the social sciences are individual interviews and participant observation in groups. Participant observation allows us to collect data in a more naturalistic setting. The problem is that we do not always have access to these settings where people discuss the topics of interest to us.

The advantage of individual interviews is that substantially more ideas are generated than in focus groups. Morgan (1988) quoted an earlier study which showed that focus groups generated only about 70% of the non-duplicate ideas of individual interviews. Individual interviews provide the most control over the data that is generated. The disadvantages of individual interviews are reflected in the advantages of focus groups discussed at length below.

The advantages of focus groups are: 1) the ability to observe interaction on a topic, 2) the give-and-take of a group which leads to more spontaneous responses, 3) the fact that participants' interactions can give insight into other behaviors beyond the topic in question. All three methods have their strengths and weaknesses. Morgan (1988) suggested that focus groups are better suited to topics of attitudes and cognitions. He also concluded that the question of which method is better is an empirical one.

The choice of which method to use will depend on the researcher's goals. Focus groups provide the opportunity to collect data from groups discussing topics of interest to the researchers. They are more controlled than participant observation but less controlled than individual interviews. It takes less time to interview participants in a group than doing individual interviews. By moderating a focus group on a pre-selected topic, the data collected will lean towards the researcher's stated goals (Morgan, 1988).

The first question to answer is, are focus groups a workable alternative to other qualitative methods for the research in question? Second, are focus groups preferred over other qualitative methods for the research in question? Morgan (1988) recommended a simple test: ask how actively and easily would the participants discuss the topic of the research. He also recommended that researchers be liberal in assessing their workability for a given project because of the limited exploration of focus groups by social scientist. Focus groups can be used as the sole data collection method. The current research is considered to be self-contained focus group research.

Focus groups can also be used as an adjunct to other qualitative or quantitative data collection methods. The goal in both cases is to get closer to the participants' understanding of the research topic of interest. Morgan (1988) emphasized learning about the participants' experiences and perspectives. He preferred perspectives because it implies a broader basis for specific attitudes and opinions. Focus groups are useful when it comes to investigating what participants think but excel at uncovering why participants think as they do (Morgan, 1988).

The following chapters discuss: 5.1 Modern Qualitative Research Theory, 5.2 Grounded Theory, 5.3 Using Focus Groups with Children, 5.4 The Moderator, 5.5 Working with Children, and 5.6 Research Question.

5.1. Modern Qualitative Research Theory

Traditional research in the social sciences has been characterized by the following: formulating hypotheses, testing them statistically, developing scales and questionnaires, attempting to control for extraneous variables by using control groups, and striving to generalize from a sample to an entire population. Recently, researchers have begun to focus on the subjective experience, diversity, and historical context (Auerbach et al., 2003). This type of research is broadly labeled qualitative research. Qualitative research is diverse and includes: participant observation, field work, ethnography, unstructured interviews, life history, textual analysis, discourse analysis, critical cultural history, and more. According to Auerbach et al. (2003) "Qualitative research is research that involves analyzing and interpreting text and interviews in order to discover meaningful patterns descriptive of a particular phenomenon." The qualitative approach to research design leads to hypothesis-generating research rather than hypothesis-testing research used by the quantitative approaches.

5.2. Grounded Theory

According to Auerbach et al. (2003), traditional research begins with a hypothesis. It then chooses independent and dependent variables and collects data with the aim of testing whether the relationship between the variables (stated hypothesis) is true using statistics. Qualitative research uses the grounded theory method. In grounded theory one do not need to have a hypothesis when one begin. It also allow for the use of subjective experience. Hypotheses are developed by listening to what is said. The hypothesis is developed after the data is collected. The grounded theory method has two basic principles: (1) questioning rather than measuring; and (2) generating hypothesis using theoretical coding. Researchers may not know enough about a topic to formulate a hypothesis. Grounded theory allows researchers to use participants as a source of knowledge. They are experiencing the phenomena directly. The participants are questioned about their subjective experience, and hypotheses are generated from their responses (Auerbach et al., 2003). The data that is gathered from the participants undergoes a methodology called theoretical coding. This method will be described in detail as a hypothesis is developed for a research topic

5.3. Using Focus Groups with Children

In an article on focus groups with children, Gibson (2007) outlined that the use of focus groups involves the sequential steps of preparation, implementation, analysis and interpretation and defines a focus group as “a carefully planned discussion, designed to obtain perceptions on a defined area of interest in a permissive, non-threatening environment”. The aim of a focus group is not to develop consensus but to produce qualitative data that provides insight into the attitudes, perceptions, motivations, concerns and opinions of participants.

Age should dictate the size of the group. Working with groups of four to six children, ages 6-10 years old, led to lively discussion and activity was manageable. Even with four young people in one study rich data was still possible (Gibson, 2007). In describing some of their research,

Morgan et al. (2002) reported that their groups ranged in size from two to seven children. Their experience suggests that four or five participants are probably ideal, especially with younger children aged 7–8 years. Probably four to five participants are ideal with younger groups but groups as small as two were used (Morgan et al., 2002). Morgan et al. (2002) wrote that groups of two or three did not really constitute a focus group but tended toward serial interviews, where the facilitator spoke to each participant in turn and discussion between participants was reduced.

Discussions lasting much over 45 minutes resulted in the quality of responses beginning to deteriorate. Their experience indicated that two sessions of about 20 minutes, separated by a break for refreshments are probably optimum for 7–11-year-olds (Morgan et al., 2002). Variation in age in groups must also be considered. There should only be one–two year age difference between participants, since style, ability, sensitivities and level of comprehension and abstraction differ substantially at different ages (Gibson, 2007). Permitting ‘fiddling’ with toys also appeared to facilitate participation and may have a positive effect of relaxing children by providing respite from eye contact with the group and facilitators; without necessarily interfering with concentration (Morgan et al., 2002).

5.4. The Moderator

A key task for the facilitator is to maintain an appropriate balance of power in terms of directing and controlling the group; and creating an atmosphere in which participants feel free to contribute. This task poses a greater challenge with children in view of the inherent power imbalance and the tendency to view the facilitator as an authority figure, such as a teacher, and to respond accordingly (Morgan et al., 2002). The moderator facilitates discussion in a non-directive and unbiased way, using pre-determined questions. A circular arrangement may be best and permits the group moderator(s) to sit among participants projecting a non-authoritarian climate. Choosing to sit on chairs or on the floor will be an age-dependent question: whatever one thinks will give a relaxed and informal atmosphere. The inclusion of a table is a personal choice, but it can make children and young people feel less self-conscious (Gibson, 2007).

Gibson (2007) discussed three important functions of the moderator's role: 1) to make the group feel comfortable and at ease, 2) to keep the group discussion focused on the topic, and 3) to ensure that all children and young people have the opportunity to contribute as well as to seek clarification to ensure that an accurate account of their view is captured. Mastering moderation is to successfully moderate the four important phases of the group: beginnings, openings, discussion and wrap-up.

According to Gibson (2007), a standard statement read aloud to each group is highly recommended to ensure that each group receives the same information and nothing important is missed. The format and nature of the group discussion will need to be outlined in this statement. Some ground rules are helpful such as avoiding talking at the same time and that there are no right or wrong answers because this is not a test. One should make it clear to the participants why they have been asked to participate. The initial opening question and the sequencing of questions that follow must be well thought out. There should be a pre-determined structure, listing the topics to be discussed, that allows for flexibility and space for participants to offer contributions on topics important to them, particularly for young children (Gibson, 2007).

A further decision to be made in the planning stage is the inclusion of exercises or activities. Their inclusion is an excellent strategy to maintain children's concentration and interest as well as enabling participants to work together. They can also be helpful as a fun warm-up session when children first arrive at a group. One's decision will be based on the way in which one wants the discussion to be organized, reflective of one's study and overall aim (Gibson, 2007).

5.5. Working With Children

Because many children and young people may not have participated in a focus group, clarity from the start is crucial (Gibson, 2007). Decreasing performance anxiety is the role of the standard statement. The format and nature of the group discussion will need to be outlined in the opening statement; alongside reminders about confidentiality and what this means in a way that children will understand (Gibson, 2007). Some ground rules are helpful such as avoiding talking at the same time, how to attract attention when wanting to speak, and that there are no right or wrong answers as this is not a test (unlike classroom work). The aim of the discussion and how long the group will last are all important issues to communicate about at this stage. Approaches to presenting questions should also be considered, with the use of 'what' or 'how' questions preferred to 'why' questions and those that initiate 'yes' or 'no' responses. Relevant, sensitive probes for explanation, checking meaning and clarification are helpful, aimed at individuals as well as the whole group. Using phrases such as, 'what does everyone else think', 'does anyone think something different' as opposed to directing a question at an individual who may be shy is a preferred method. Or going round each member of the group and calling on the children by name can be a useful strategy with young children who might be excited and all talking at once. Time available will be an important factor. Younger children can be kept focused on an activity for about 45 minutes to one hour; whereas older children and young people, with good moderator skills, will maintain focus for about 90 minutes. Intense group discussion may give rise to stress or distress in individuals (Gibson, 2007).

Morgan et al. (2002) reported on their research experience. The topic areas covered were children's perception of asthma triggers, their use of asthma treatments, the experience of asthma at home and at school, and their perceptions of good and bad things about having asthma. Eleven focus groups were conducted, involving a total of 42 children aged 7–11 years; who were drawn from a socio-economically and ethnically mixed urban area. An experienced facilitator and co-facilitator conducted the groups. One facilitator led the discussion, and the second operated the tape recorder, assisted with the discussion and observed group dynamics. A third person was present in the background for five of the eleven groups to observe the group and take field notes. The focus groups conducted provided new insights into children's own experiences of living with asthma; and identified some important differences from adults' priorities and concerns.

5.6. Research Question

Grounded theory does not require the researcher to have a specific research hypothesis when they begin. However, a research question can help focus the effort to setup the research and select participants to collect the data required. In this case, there were a number of theories about tutoring effectiveness but there was no one that had universal agreement. One broad question was chosen as the focus of this research: What makes tutoring effective?

CHAPTER 6

Research Results

6.1. Qualitative Research Results

Two schools were involved in this research study. There were three students from the Arts Based Elementary School and eleven students from the Carter G, Woodson School of Challenge, both in Winston-Salem North Carolina. All were third graders. The instructions given to the school officials were to select students who could benefit from tutoring in multicolumn addition or who were studying it in school, if possible. The parents were required sign consent form (See Appendix C) to allow the children to participate. Three different focus groups were conducted with groups of three, five, and six children. Some of the grammar in the data below is not correct according to standard usage, but a choice was made to stay as close as possible to the actual expressions of the participants.

Upon entering the room, the students were greeted. Initially the seating was random because there were tasks to do prior to participating in the focus group. It was explained to the students that they were free to participate and free to decline to participate. They all chose to sign their assent forms (see Appendix D) and participate. The students were allowed to select a focus group name from a list of colors. They seemed to like this bit of role-play using made-up names. They signed their assent forms with their true names, but their focus group names were used when referring to them out loud and on the worksheet and warm-up questions form. The students were asked to fill out a form with a few warm-up questions about their tutoring experience. These questions were intended to encourage the students to participate by answering benign questions. The students were also asked to complete a worksheet with eleven multicolumn addition problems similar to what they would solve on the computer tutor a little later. While the students were working with the form and worksheet, they were called one by one to solve multicolumn addition problems using a computer tutor. The tutor provided feedback in the form of colors (red for wrong, blue or green for correct.); and hints, which were under the students control. The student could ask for hints when needed or use the automatic color feedback to determine when something was wrong. The computer kept track of when the students made sum or carry errors and when they used hints. After all the students had completed the forms and worksheets; and taken turns with the computer tutor, they were ready for the focus group.

The form chosen was a roughly circular seating arrangement. The students held tags with their focus group names on them so that the moderator could remember what to call them and they could remember what to call each other. The sessions began by asking the warm-up questions. There were slight variations in the questions from group to group. There were some questions about the tutoring program not included here because of the nature of the questions. The lists of questions were generally as follows:

Warm-up Questions:

Have you ever used a tutoring program before?

Do you think the tutoring program helped you?

Have you ever had a person help you as a tutor?

Do you think they helped you?

Core Questions:

> If you're trying to solve a problem, and somebody gives you the answer. Do you think that helps you?
>
> What if they were trying to help you, instead of giving you the answer they just gave you a clue? Do you think that's helpful?
>
> Now let's say you had a problem that was really hard, so hard that you didn't even know what to do to solve the problem. What do you think you would do in a situation like that?

Open-ended Question:

> How do you think a tutoring program should help you? What do you think it should do?

The discussions for each session were recorded. A transcript was created from the dialog for each session (see Appendix E).

6.1.1. Repeating Ideas.

The transcripts of each session contained responses of the recipients. The responses were farmed to extract ideas they contained. Some of the ideas were repeated within the group and between groups. Individual phrases were combined into groups expressing similar thoughts. Each group of similar thoughts is considered a repeating idea. The initial combined transcript consisted of the repeating ideas from all three focus groups. Not all repeating ideas were considered relevant to the research question being considered. They were omitted. Following are the repeating ideas from the combined transcripts. The numbers represent the initial order in which the repeating idea category was created. A letter after a number means the group was split.

Repeating Idea #1 - Learning by doing it yourself

- You need to learn and do it by yourself.
- If someone tells you the answer you don't really get it.
- If they do it for you, because you don't know how to do it then.
- I don't think you can really learn like that because they're doing it for you.
- let you try to figure it out

Repeating Idea #2 - Getting a little help is ok but too much doesn't help

- Find your own mistake
- ask the teacher for a hint
- You could try figuring it out and if you don't get it you could ask somebody at your table to help
- Well you could think about it and solve the problem.
- If someone tells you the answer they are not helping you.
- It is not going to help
- It is not going to help.
- They are not helping you
- Sometimes when they give you a hint it can be to close to the answer.

Repeating Idea #5 – Figuring things out for yourself

- They can give you a hint and you can find the answer for yourself.
- You want to figure it out yourself.
- It would be much better as long as they don't give you the answer
- It is right because they'll give you a hint
- If you give a little hint the person would be able to figure out the answer.
- You want to figure out the problem by yourself and they just give you a little hint.
- You are not going to be able to learn because they are telling you.
- But, just a little, teeny hint, not a big hint.
- If they give you a hint that is not close to the answer but a little close to the answer it can be all right.

Repeating Idea #10 – Getting the answer yourself is important

- I wouldn’t learn unless they sit down and teach me and ease me through the way to get the answer.
- That would be helpful. Then after you try to solve the problem and they came to check on you and they said it wasn’t right and then you would get it right because you did it all over. Then if you have more problems you will get them all right.
- I think that would be helpful because, they are trying to give a little hint so that you can get the problem right all on your own.
- A hint is better because it is not giving you the answer but it is helping you get the answer, in a different way.

Repeating Idea #8 – Just getting the answer isn’t learning

- I am not learning anything if they just tell me the answer.
- They just gave you the answer.
- No, I don’t think it is helpful because if you gave me the answer I haven’t done anything and I won’t be helped.

Repeating Idea #3A – You need to show how you got the answer

- It is not fair because they are going to give you a hint and you have to show the answer and you are not going to know how to show the answer.
- They gave you too much of a hint you are not going to be able to show the answer.

Repeating Idea #4 – Too much help is cheating

- They are just cheating.
- It would be cheating.
- If they give you too much of a hint now you got the answer and your teacher thinks you cheated.
- If the teacher ask you how you got the answer and you don’t know she’ll say you don’t know how to get the answer in her notes.

Repeating Idea # 7 – They may give you the wrong answer

- They might tell you the wrong answer and they might put you back in the same grade you are right now.
- They are going to tell you the wrong answer and you are going to put it down and get retained.

Repeating Idea # 6 – Passing the EOG is important

- If you are trying to pass the EOG
- Someone is not going to give you the answer on the EOG.

Repeating Idea #9 – Passing the grade, EOG or other test are important

- When I take the EOG they won't be there to help me.
- You won't be here to help in school or in college.
- So you can learn how to do the same question on the EOG or another quiz that you might take.
- If you want to pass the grade and you don't know it and you are trying to figure it out

6.1.2. Themes.

Next, repeating groups that expressed related ideas were combined together into a common theme. A single word was applied to each group to help solidify the concept expressed by that group. Although this not a part of the current theories of qualitative data analysis, it was helpful in keeping a clear distinction between the concepts that needed to be managed.

Philosophy

Theme: Learn to solve problems with minimal help

Repeating Idea #1 - Learning by doing it yourself

Repeating Idea #2 - Getting a little help is ok but too much doesn't help

Repeating Idea #5 – Figuring things out for yourself

Repeating Idea #10 – Getting the answer yourself is important

Reasoning

Theme: Learning for self avoids problems

Repeating Idea #8 – Just getting the answer isn't learning

Repeating Idea #3A – You need to show how you got the answer

Repeating Idea #4 – Too much help is cheating

Repeating Idea # 7 – They may give you the wrong answer

Consequences

Theme: There are consequences associated with not learning how to find the answer.

Repeating Idea # 6 – Passing the EOG is important

Repeating Idea #9 – Passing the grade, EOG or other tests are important

6.1.3. Theoretical Construct.

Once the repeating ideas are grouped into themes, then the themes are grouped into theoretical constructs. In the case of this research all three themes were covered by a single theoretical construct.

Theoretical Construct: Minimally Intrusive Teaching Strategy

Theme: Learn to solve problems with minimal help

Theme: Learning for self avoids problems

Theme: There are consequences associated with not learning how to find the answer.

6.1.4. Theoretical Narrative.

The theoretical narrative is created by using theoretical constructs to organize subjective experiences into a coherent story. In the case of this research, the theoretical construct Minimally Invasive Teaching Strategy was used to define the research results.

Theoretical Narrative

It has been proven conclusively that tutoring is effective. However, the question of what makes tutoring effective is still subject to debate. When the children in this study were asked to think about tutoring and how it should be applied to them, they consistently chose a process that let them do most of the work themselves (*Minimally Invasive Teaching Strategy*). Their reasoning indicated that they believed that it was the moral as well as the practical thing to do. They also understood that there were negative consequences associated with not learning how to do the work themselves. Although the students recognized that there were positive consequences to learning, there seemed to be a disproportionate focus on the negative consequences of not learning.

6.1.5. Evaluating Qualitative Research Results.

Auerbach et al. (2003) defined a process for evaluating qualitative research results. He recommended that qualitative research use the following to evaluate research results: Justifiability of interpretations and Transferability of theoretical constructs. In order for an interpretation to be justifiable, it must have transparency, communicability, and coherence. Transparency requires that other researchers know step by step how one arrived at one's interpretation. It does not mean that they have to agree with you. Communicability means that one's themes and constructs can be understood by and make sense to other researchers. This does not mean that other researchers would have come up with the same constructs or agree with the one suggested. If one can describe one's themes and theoretical constructs to other researchers and they understand then they are communicable. Coherence means that ones theoretical constructs must fit together and allow a coherent story to be told. The story should help to organize the data. This may not be the only story that can be told by the data. In order for theoretical constructs to be transferable the must be extendable beyond the particular sample researched. The specific pattern may relate to the subculture being studied, but the more abstract patterns should be found in other subcultures.

6.2. Quantitative Research Results

A quantitative area of research was also carried out as a precursor to the focus groups. A tutor was developed to use a simple interface and single language design, production rules, constraints, hints text, hint dialog, and to implement the five step dialog frame. The purpose is to show that this type of design is effective in helping students to solve problems. Students were asked to use a tutoring program to solve multicolumn addition problems in two ways. They were asked to solve eleven problems on paper. They were also asked to solve other problems using the computerized addition tutor. On one problem, the students were introduced to the features of the program then asked to solve several others on their own. The results are given in the tables below. Table 6.1 shows the research results for the first group of students, Table 6.2 shows the research results for the second group of students, and Table 6.3 shows the research results for the third group of students. The left side of the tables shows the actions recorded by the tutoring program. The students' actions are recorded as carry errors, sum errors, and hints used. Under "Help" on the right side of the table is the summary of help received on all problems by each student. Individual errors are not necessarily counted. Under "Worksheet" on the right side of the table are the scores the students received base on the number of problems the student solved correctly.

Table 6.1 Calculation Results Group 1

Calculation Results Group 1									
Tutoring Program						Help		Worksheet	
	Problem	Sum Error	Carry Error	Hint		#Hints	#Errors	Score	Errors
Red1	1	3	0	0		0	1	11	
	2	0	0	0					
	3	0	0	0					
	4	1	0	1					
Green1	1	0	0	0		2	2	10	
	2	0	1	1					
	3	2	0	1					
	4	0	0	1					
Violet1	1	0	0	0		0	1	11	
	2	0	0	0					
	3	0	0	1					
	4	0	0	0					
	5	1	0	0					

Table 6.2 Calculation Results Group 2

Calculation Results Group 2									
Tutoring Program						Help		Worksheet	
	Problem	Sum Error	Carry Error	Hint		#Hints	#Errors	Score	Errors
Red2	1	1	0	1		0	2	11	
	2	0	0	0					
	3	2	1	0					
	4	0	0	0					
Blue2	1	2	0	1		0	1	11	
	2	2	0	0					
	3	0	0	0					
	4	0	1	0					
Gold2	1	x	x	x	NOS	4	3	6	
	2	3	0	2					
	3	0	0	2					
	4	1	1	1					
Violet2	1	0	0	1		0	3	11	
	2	0	0	0					
	3	1	0	0					
	4	0	0	0					
	5	2	1	0					
Fuchsia2	1	x	x	x	NOS	2	1	11	
	2	2	0	1					
	3	0	0	0					
	4	0	0	0					
	5	0	0	2					

Table 6.3 Calculation Results Group 3

Calculation Results Group 3									
Tutoring Program						Help		Worksheet	
	Problem	Sum Error	Carry Error	Hint		#Hints	#Errors	Score	Errors
Silver3	1	2	0	1		0	2	0	
	2	1	0	0	NOS				
	3	0	0	0					
	4	0	0	0					
	5	0	0	0	NOS				
	6	1	0	0	NOS				
Green3	1	2	0	1		1	2		
	2	0	0	0				10	
	3	0	0	0					
	4	1	0	0					
	5	1	0	1					
Gold3	1	3	0	1		1	3	10	
	2	1	0	0					
	3	7	0	2					
	4	0	0	0					
	5	1	0	0					
Red3	1	0	0	1		2	1	10	
	2	2	0	3					
	3	0	0	1					
Indigo3	1	3	0	4		2	2	10	
	2	0	0	1					
	3	0	0	3					
	4	0	6	0					
	5	1	0	0					
Gray3	1	5	14	4		5	1	0	
	2	2	0	6					
	3	0	0	7					
	4	0	0	7					
	5	0	0	3					
	6	0	0	6					

The question we were interested in answering was, would students use the tools of scaffolding for student construction to help solve problems if they needed help. In the case of this experiment, the color red indicated errors and the optional action of choosing hints at any step was available to the participants. The results indicated that the students did use the available tools to successfully solve some problems. Most of the students were successful at solving problems working on paper, but even those that did not solve problems successfully on paper were able to successfully solve problems on the computer with assistance solely from the computer. What was not tested was whether the program could be used for learning. There was not time available to use the tutor as the sole learning tool for the students participating. Also, any impact due to the design deficiencies of the interface is not considered.

The focus group guide in Appendix A documents the methodology we intended to use for the focus group. We needed to deviate from it slightly. There were more error codes than were necessary for the final tutor design at this stage of the research. Only three codes were used by the program: sum error (sue), carry error (cae), and no solution (nos) when the student never reached the goal.

CHAPTER 7

Conclusions and Recommendations

This research project made use of current tutoring theory to develop a tutor. . The tutor was designed to scaffold for student construction, help students resolve impasses, provide positive and negative feedback, and use a five step dialog frame. The cognitive model used productions from ACT-R theory. The results of this research indicate that current tutoring theories implemented by this research are valid and that they can be used to develop simplified tutoring systems for topics in elementary arithmetic. Complex systems may be required for tutoring at higher levels of mathematics. However, the research performed for the multicolumn addition tutor cannot provide guidance one way or the other. The qualitative research used focus groups and theoretical coding to develop a hypothesis of what makes tutoring effective. The hypothesis can be stated as: Tutoring will be effective when the student is taught only what is necessary to get through an impasse or correct errors.

The next phase of the research should implement buggy student models and use those models to help modify instructions presented to the student. In this manner, learning can be measured by changes in the model over time. The results of this research should be used to design other tutors for elementary arithmetic topics.

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APPENDIX A

Focus Group Guide

Thesis TiTle: Determining the effectiveness of a multicolumn addition tutoring program
Thesis Date: Spring 2012
Method: Focus Group with Experiment
Topic: Tutoring Systems
Target Audience: Tutoring System Researchers and Developers
Principal Investigator: Moise Burgess
Advisor: Albert C. Esterline

Instrument Title: Facilitating a Tutoring System Discussion Group with Children

Participant Time Required: 90 minutes
Experiment Time: 30 minutes
Focus Group Time: 45 minutes
Startup/Wrap Up: 15 minutes

Question to be answered by Focus Group Discussion:
The purpose of this focus group is to test our understanding of the research results generated by the participants interacting with the tutoring program. It should also help us interpret discrepancies between anticipated and actual results. The expectation of this focus group is that it will help determine the effectiveness of a tutoring program based on research surrounding scaffolding and student construction in human tutoring.

Focus Group Methodology:
The method used will be a combined approach using research and experimental data from students interacting with the tutoring program, with focus group discussion results to provide dual data sources. The focus group time is reduced to 45 minutes due the young age of the participants.

Discussion Group Guide

1) Preparation
    a) Memorize the step by step process for the group
        i) List in order what will occur from an agenda
            (1) Setup the computer and start the program
            (2) Welcome the students when they arrive

(3) Assign or allow participants to choose aliases
(4) Let the participants know that they will receive a gift at the end of the session
(5) Introduce the researchers
(6) Let the students use the tutoring program
(7) Organize the focus group
(8) Let the participants know that they will be recorded
(9) Moderate the discussion
(10) Wrap Up the discussion
(11) Let the school administrator pass out the gift

b) Allow the participants to choose an alias to be used during the rest of the session
   i) The name should consist of a color and a number from the name list
   ii) The alias will be worn by the participant around the neck on a hangtag

Students will choose a code name based on a color and/or a number. This will be used instead of their real names during data entry and discussions. All students will begin working with paper and pencil. Then, while one student is working with the tutoring system the other students will be working with pencil and paper on problems of the same type. This will give them immediate experience to contrast traditional problem solving with a tutor.

c) Seat the children comfortably according to facilities
d) Give the children a sheet of arithmetic problems to work on while they wait for their turn on the computer.
   i) The children should use their alias to identify their worksheets
   ii) Explain to the students the term multicolumn addition and what it means to insure that they have an understanding.

In single column addition the entire sum at the bottom of the column. In Multicolumn addition when the result is greater than nine, the tens digit is carried to the top of the next column.

e) Give the children a short survey sheet to fill out while they wait for their turn on the computer
   i) The children should use their alias to identify their survey sheets
   ii) The survey sheet should answer key questions
      (1) Have you ever used tutoring programs
      (2) If yes, have the programs helped you
      (3) Have you ever had a human tutor
      (4) If yes, did the human tutor help you

These questions are intended to gather the experiences and attitudes of students towards tutors both human and computer.

f) Have the children work at the computer
   i) Call each child up in turn
   ii) Explain how to use the program
   iii) All participants should identify themselves by their alias
   iv) Let the child work through three problems

2) Focus Group Moderation
   a) Researchers Opening Statement
      i) Let the child know that they can refuse to answer any question or withdraw from the discussion at any time

      What you have just done is solve multicolumn addition problems. I would like your honest feedback during the discussion of the program. You don't have to agree with me or each other. You can have your own opinion. You don't have to say what we want to hear. We are trying to determine if tutoring programs can help children help from parents or teachers

   b) Discussion Group Guidelines
      i) The participants should be addressed only by their alias
      ii) Participants should not interrupt another while another child is speaking
      iii) Participants who want to speak should raise their hand
      iv) The moderator will call on any of participants who are quiet
      v) The moderator will rein in participants who dominate the discussion
      vi) Ask the ice breaker questions right after the introduction

   c) Have each child make an opening statement for identification and to establish an initial position
      i) Let the participants know that we are here to learn from them
      ii) Let the participants know that they are helping with an important research problem
      iii) Ask a warm-up question

      Ask the questions from the survey sheet. If students have not had tutoring of any kind before ask the following questions of those students: What is tutoring? Why do students get tutoring?

   d) Ask the question in the order specified but adapt to unexpected situations

   The questions proposed for discussed will fall into 4 categories:

(1) Program Mechanics
(2) Tutor Behavior
(3) Individual Experience
(4) Suggestions For Improvements

The number at the end of the question indicates which category it belongs. The moderator will determine the order of questions after the initial ice breakers. The moderator is also responsible of synthesizing topics from questions.

Have you ever used a tutoring program for math before? (3)
What kind of programs have you used? (3)
The purpose of these questions is to provide a framework for understanding the rest of the students' responses. If they have never used a tutoring program before they may have unrealistic expectations and the discussion can address that issue. Their expectations may be shaped by programs they have used in the past.

How should a tutoring program help you? (4)
What should a tutoring program do? (4)
This question is intended to elicit generic information from the student on their expectations about a tutoring program without focusing on the one they just used.

Did you like being able to ask for hints? (2)
What did the red numbers in the program mean? (2)
What did the blue numbers in the program mean? (2)
These questions attempt to elicit feedback on particular features. This feature is important when scaffolding for student construction. This question is intended to see if the students understand that the text color is another form of hint that attempts to assist them in finding a correct solution.

Was it easy to enter numbers into the program? (1)
Did it feel like the way you did multicolumn addition on paper? (1)
Was it useful to have the computer solve the problem for you? (1)
These questions will separate the reaction to the physical environment of using the computer from the reaction to the tutoring elements of the environment.

Why didn't the program stop if you gave a wrong answer? (2)
The purpose of this question is to see if the students perceived a feature set up for scaffolding as negative. The program provides a hint in the form of red text but does not stop the student from proceeding.

What did you not like about the program you just used? (4)
Was the program easy to use? (4)
Were the instructions in the program easy to use? (4)
The purpose here is to get constructive feedback on the features of the program that need improving.

Is there anything you liked about the program you just used? (3)
The purpose here is to get positive feedback about the program's good attributes.

Do you think a program like this can help you do better in Multi-column addition? (3)
Do you like multiplication? (3)
The purpose of this question is to get an overall opinion of whether this program is design and structured properly to help students learn?

e) Closing Remarks
   i) Get a final statement from each participant on what they would like to say about tutoring
   ii) Thank the participants
f) Let the school administrator pass out gifts

3) Coding the results
   a) Coding Tutoring Program Results (Experiment)

The results recorded by the tutoring program will be coded as follows:

NOE	Answer without errors
ACE	Auto correct error
CAH	Correct after hint
CAP	Correct after passing errors
NOS	No solution, could not solve problem
SUE	Sum error
CAE	Carry error
ERC	Erroneous carry
RSC	Reverse sum and carry
NSU	No sum
WRS	Wrong sum
WRC	Wrong carry

b) Coding the Discussion Group Results

Coding is not feasible in this case with limited experience working with focus group. A theory has not been developed to allow a coding model to be created in advance of collecting the focus group data. The results recorded from the focus group discussion will be coded after they are transcribed. A theory of what the focus group contributed can then be developed based on the results.

APPENDIX B

Tutoring Interface Technology

1. INTERFACE TECHNOLOGY

The evolution of interface technologies will directly affect the type and quality of tutor interfaces we can build. The communications interface between the tutor and the student is now a key component of intelligent tutoring systems. The human-computer interface (Shneiderman et al., 2010) is a separate area of research that seeks to determine the most effective way to design interfaces to enhance human to computer interaction and human to human interaction that uses a computer interface. Most current interfaces are evolving towards greater direct manipulation by the user. Synthesized speech is also becoming more omnipresent where it is beneficial. (Walker et al., 2005) Avatars are animated helpers (ARYA, 2009). They can be found in many teaching applications, and the World Wide Web is evolving its own suite of applications.

1.1. Interface Design

Graphical User Interfaces (GUIs) are the foundation of the most common type of interfaces used with computers. When using direct manipulation, the action or result is visible as icons or WYSIWYG (What you see is what you get) type, and the action is natural, such as dragging, deleting, or formatting. The action or result is immediate, as can be seen in changes in the objects. The action is easily reversible because one can undo any changes.

1.2. Speech Technology

What are called speech sounds are created by vibrations of the human vocal tract (Carmell, 1997):. The sounds usually travel through the air. We can hear them with our ears or record them through a microphone. In some ways, speech is just a sound like other sounds, but somehow our brains have the capability to extract meanings from certain groups of sounds. The vibrations that we consider to be speech sounds can be represented by speech waveforms. Figure B.1 shows a speech waveform with a phrase spoken by a specific individual. This waveform would be different for another person speaking the same word.

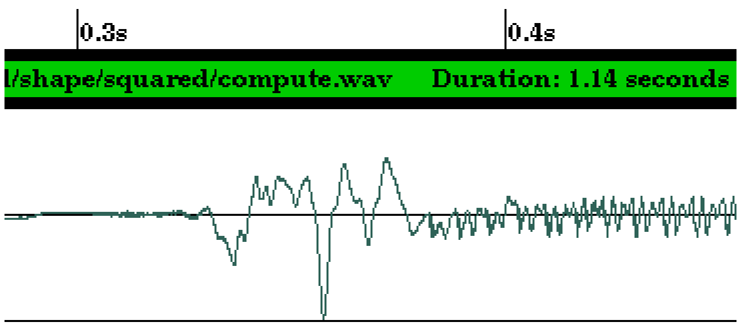

Figure B.1 - Speech waveform for the "pu" portion of the word "compute" pronounced by Tim Carmell. (Carmell, 1997)

It is not possible to read the phonemes of speech directly from a waveform, but we can separate the waveform into its frequency components and obtain a spectrogram that can be deciphered. A spectrogram is a translation into the visual domain of speech and other sounds, which we normally process with our ears.

Speech sounds used in a language fall into categories called phonemes. American English, for example, has about 41 phonemes. Phonemes are abstract categories that allow us to group together subsets of speech sounds. All of the phonemes classified into one phoneme category are similar enough so that they have the same phonetic properties. Phonemes can be classified into the following broad categories (Carmell, 1997):

VOWELS

1. **Monophthongs** - American English has about eleven vowels having a single vowel quality
2. **Diphthongs** - American English has six diphthongs - vowels which manifest a clear change in quality from start to end.

CONSONANTS

1. **Approximants -** English has four approximants or semivowels
2. **Nasals** - English has three nasals, in which the airflow is blocked completely at some point in the oral tract.
3. **Fricatives** - English has nine fricatives - weak or strong friction noises produced when the articulators are close enough together to cause turbulence in the airflow
4. **Plosives -** English has six bursts or explosive sounds, produced by complete closure of the vocal tract followed by a rapid release of the closure.

5. **Affricates** - English has two affricates - plosives released with frication.

Speech sounds directed into a microphone are converted into variations in electrical voltage levels. Computers equipped with the proper hardware can convert the analog voltage variations into digital sound waveforms by a process called analog-to-digital conversion (ADC), which involves two separate components (Carmell, 1997):

Sampling – First a reading is taken of the sound periodically in equal increments of time. This is anywhere from 8,000 times per second for standard telephone signals to 20,000 or more times per second for stereo music. For voice synthesis and recognition, it may be about 16,000. The higher your sampling frequency, the better the sound reproduction, but at a higher storage and processing cost.

Quantization – Once one samples a signal and obtains the amplitude of that sample, the level can be adjusted to a quantization level (closest allowable value) for that sample. The accuracy to the original waveform is determined by the number of levels. 256 steps allow for 8 bit representation, and 65636 steps allow for 16 bit representation. Once a waveform is digitized, it can be stored as a file on a computer. These can be accessed by tutors as part of an interface.

1.3. Speech Tools

Text to speech engines take the printed word and convert it to speech sounds through the reverse of the process described in section 4.2 (Shneiderman et al., 2010). The same or similar techniques are used to begin with the words one wants to speak and then synthesize acceptable output that accurately represents the intended speech. The process is called speech synthesis. Speech recognition is the ability to translate speech sounds into words. Natural language understanding is the ability to comprehend the meaning of a string of words in a sentence and respond appropriately. Today, the ability to talk to a computer using rudimentary natural language is being implemented as phone answering systems that collect keywords from natural speech to direct calls. Users often have a choice of input types (Shneiderman et al., 2010). These options have become more important as prosody (emotional state indicated by features, voice stress, etc.) is being used to enhance communications between computers and humans. Some of the tools available to experiment with speech generation are given below.

FreeTTS (Walker et al 2005) is a speech synthesizer that converts source text into speech. Different voices can be used in the design of applications that are implemented based on the FreeTTS model.

Baldi Sync is part of the CSLU Toolkit (Hosom, 2009), a comprehensive suite of tools to enable research into speech and human-computer interaction. Baldi Sync synchronizes a voice guided by text or a .wav file with an animated avatar that moves in sync with the spoken word. Figure B.2 compares four different aspects of speech sounds. The sound itself, of course, cannot be heard from the picture.

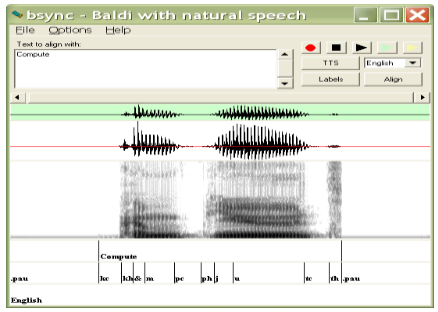

Figure B.2 – This is the Baldi-sync (Hosom, 2009) tool. It is used to align text or voice input to speech output. It demonstrates the correlation between speech sounds, speech waveforms, spectrograms, and phonemes.

1.4. Avatars

Avatars are animated heads or characters whose movements can be synchronized to voice output. When the synchronization is done well, it is because the lip movements are synchronized to the phonemes in the spoken words. The other movements may require an understanding of prosody or the facial expressions that indicate emotions. (Anderson et al., 1995) recommended that computer-based tutors not be representation as humans. The appropriate use of avatars may be as part of a sophisticated interface rather than to simulate human emotional reactions.

Below is the iFace (Arya, 2009) avatar interface. One can record and load a voice file. When one plays back the voice file, the avatar will sync its movements including its lips to coincide with the speech on the file. Although the actual movements are not accurate in the demo version, working with the interface should improve this. Figure B.3 is an example of an avatar that can be configured for use with an application and a control for testing the avatar.

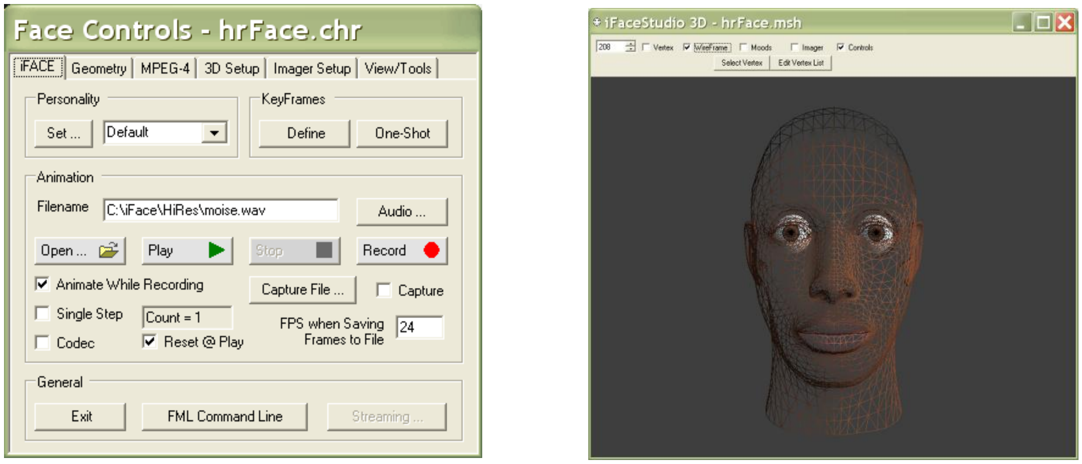

Figure B.3 – iFace Control and a Sample Avatar

The Percy Fraction Pie vocabulary tutor is an example tutor created with the CSLU toolkit. Figure B.4 is the tutorial screen that will be used to teach fractions.

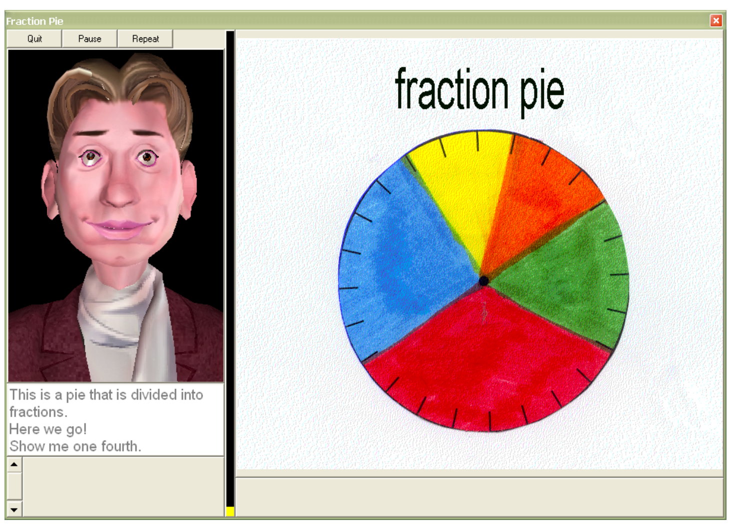

Figure B.4 – Fraction Pie Tutorial with Percy Avatar (Hosom, 2009)

1.5. Web Programming

Applications developed for the World Wide Web have an advantage. They can be used from any location with a computer and a web browser, and no software needs to be installed. If intelligent tutors can be developed for the Web, they will be available to students in almost any part of the world, twenty-four hours of the day. Tutors such at the CTAT fraction tutor (Koedinger, 2008) in Figure B.5 are developed using the Java programming language or Macromedia Flash. They can be developed into Web applications with some code modifications.

1.6. Cognitive Tutors

If developing intelligent tutoring systems were a contest, cognitive tutors would be the hands down winners. They include the most advanced and useful tutors that are being used today. A description of cognitive modeling for tutors is given in section 2.2 on pedagogy. Figure B.5 is an interface created with the tutorial for Cognitive Tutor Authoring Tools (CTAT) (Koedinger, 2008).

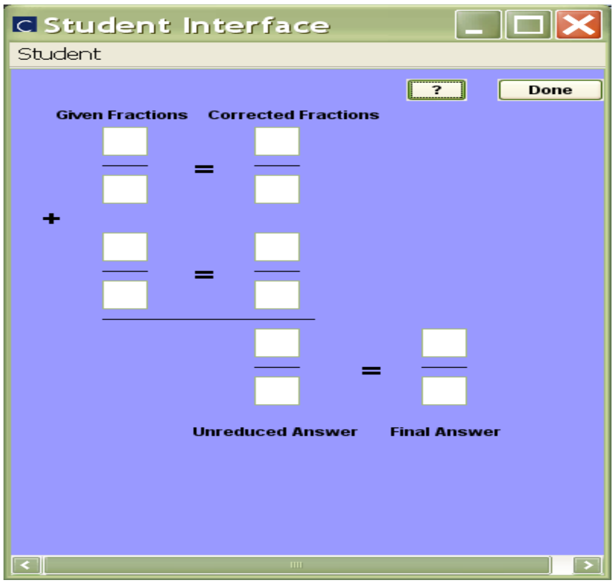

Figure B.5 – Tutoring Interface Created with CTAT (Koedinger, 2008)

The interface in Figure B.5 is used to teach fraction addition. The figure shows the stages solving the fraction addition problem from initial terms to final solution. It uses a model tracing tutor discussed in section 2.2.

1.7. Conversational Tutors

Conversational tutors use dialog similar to what takes place in class between students and instructors. The instructor tries to guide the student to the answers based on facts the students already knows. The idea behind the conversational tutor is to help the student use the facts that they know to solve new problems.

AutoTutor (Graesser, 2008) is an application that uses artificial intelligence techniques to understand natural language, computer graphics, speech intonation, and face recognition to create a Socratic style learning environment on a variety of topics. Only the textual natural language interface was available in the demo version described in this section.

The main interface design suffers from the problem of readability. The text on all pages is mostly black and white. Even the links are black and white, but they are underlined. The font style is not the easiest to read. The text is smaller and closer together than some users would find comfortable. There are a few graphics, but they do not add anything to the text. The AutoTutor demo and the Haptek player are on different websites and provide a sharp contrast in terms of font, color, and graphics. Figure B.6 shows two web pages for the AutoTutor web site.

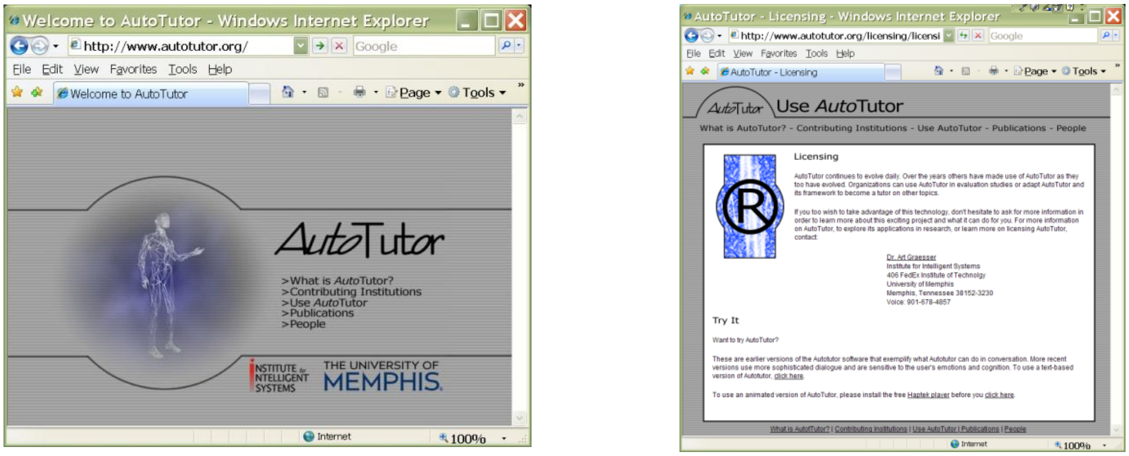

Figure B.6: AutoTutor Main and Use Pages

The Haptek Player demo has two options. There is an option for a text-only demo and a demo that uses an animated avatar. This gives flexibility to the user who may have problems downloading the required Haptek Player used with the animation option. Figure B.7 shows the Haptek Player with an avatar and a speech engine selection dialog.

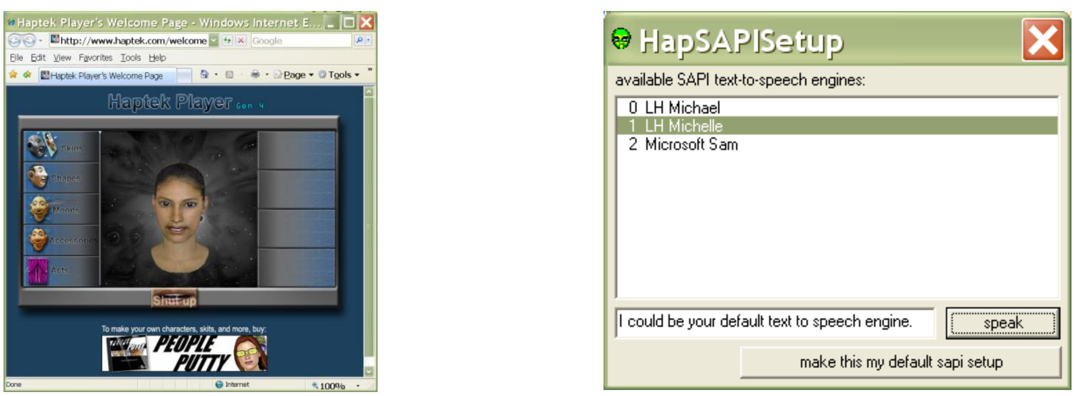

Figure B.7: – Haptek Player and Voice Choice Dialog

The text-based tutor has clear bold text that represents the tutor and an area for the student to respond. A lighter text in the tutor area represents previous responses of the student. This makes it easier to distinguish who is responding and to remember previous questions and responses. The student has a wider area to enter text in response to the tutor. The animated version has the addition of graphics but less space for text. The problem statement remains at the top of the tutoring window in both versions so that one will not lose track of what one is trying to answer. Figure B.8 shows a text based version of AutoTutor alongside a demo with an avatar.

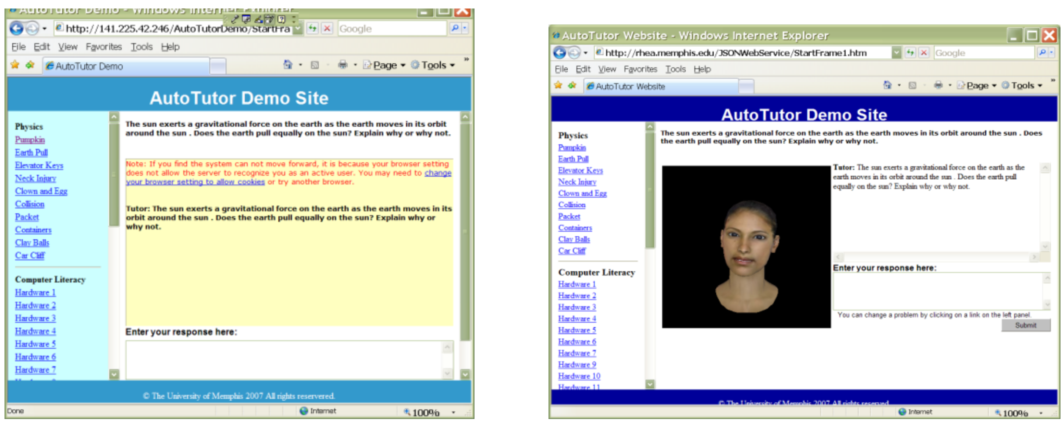

Figure B.8 – Text vs. Animated Versions of AutoTutor

The dialog interaction with the instruction module is the same except for the addition of voice output in the animated version. One will eventually get to the answer, but the logic may not always be clear.

It is clear that this technology has a way to go before replacing a human tutor. It did not recognize answers that were nearly correct but given in a different format than what the program expected. There was confusion when AutoTutor switched topics. It seemed like a different lesson. However, this is a demo, not a professional version. Those versions may address the deficiencies in this interface.

APPENDIX C

Parental Consent Form

North Carolina A&T State University

Parental Permission/Informed Consent to Participate in Research

(Determining the Effectiveness of a Multicolumn Addition Tutor)

You are being asked to allow your child to participate in a research study. Before you give your permission for your child to participate, it is important that you read the following information and ask as many questions as necessary to be sure you understand what your child will be asked to do.

Investigators:

Researcher: Moise Burgess – BSEE

Advisor: Albert Esterline – PHD

Purpose of the Study:

The study will evaluate the effectiveness of a computer tutor for multicolumn addition. Groups of six students will be needed. The students should be selected from a group that could benefit from tutoring in multicolumn addition or other elementary arithmetic topics.

Description of the Study:

If you agree to allow your child to participate, he/she will be asked to solve the following type of multicolumn addition problems on a computer.

$$\begin{array}{r} 236 \\ +\ \underline{135} \end{array}$$

Then your children, as a group, will be asked to give feedback on their experience with the program. Data will be collected by the computer while the students work. The conversation will be recorded for later transcription.

The study will take place at your child's school in a location and at a time chosen by a teacher or school administrator. The study will take 45 minutes to 1 hour.

What is Experimental in this Study:

None of the procedures used in this study are experimental in nature. The only experimental aspect of this study is the gathering of information for the purpose of analysis.

Risks or Discomforts:

Your child will be asked to type on a keyboard and view a computer screen. Your child will also be asked questions about using the program. If at any time your child feels uncomfortable they will be allowed to discontinue participation.

Benefits of the Study:

If this research is successful a line of free software will be developed for use by students who need tutoring FGMin math. The intent is to help reduce the burden on parents and teachers

Confidentiality:

Any recordings will be erased after they are transcribed. ***Your child will not be personally identified or associated with any data collected.*** Confidentiality will be maintained to the extent allowed by law.

Incentives to Participate:

A small gift will be given to each child who participates. The gift will include items such as school supplies, toys, and small amounts of candy and gum, and it will be given at the end of the session in which they participate.

Voluntary Nature of Participation:

Participation in this study is voluntary. Your decision of whether or not to allow your child to participate will not prejudice your future relations with North Carolina A & T State University or the Carter G. Woodson School of Challenge. If you decide to allow your child to participate, you are free to withdraw your consent and to discontinue his/her participation at any time without penalty or loss of benefits to which you are otherwise entitled.5

Questions about the Study:

If you have any questions about the research now, please ask. If you have questions later about the research, you may contact Moise Burgess – xxx-xxx-xxxx

If you have questions regarding your child's rights as a human subject and participant in this study, you many call the Institutional Review Board at North Carolina A&T State University for information. The telephone number of the Committee is xxx-xxx-xxxx. You may also write to the Committee at: 1601 East Market Street Greensboro, NC 27411

Agreement:

The North Carolina A&T State University Institutional Review Board has approved this consent form as signified by the Committee's stamp. The consent form must be reviewed annually and expires on the date indicated on the stamp.

Your signature below indicates that you have read the information in this document and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to allow your child to be in the study and have been told that you can change your mind and withdraw

your consent to participate at any time. You have been given a copy of this agreement. You have been told that by signing this consent document you are not giving up any of your legal rights.

______________________________	___________________________________
Name of Participant (please print)	Name of Parent/Legal Guardian (please print)
___________________________	________________
Signature of Parent/Legal Guardian	Date
______________________________	_________________
Principal Investigator	Date

APPENDIX D

Child Assent Form

North Carolina A&T State University

The Effectiveness of a Multicolumn Addition Tutor

Kid's Form for Saying Yes to Be in Research

My name is Moise Burgess and I am a researcher and scientist/teacher/student at North Carolina A&T State University. I am doing a research study and I need some help to do it.

You are invited to be in my research study about *the effectiveness of a multicolumn addition tutor*. If you and your parent say yes, I will ask you to use a tutoring program and ask you questions about the tutoring program afterwards..

I will tape your answers.

I will not videotape you.

Talking with me for this study will take about 1 hour.

You do not have to help me with this project. You can stop talking whenever you want to and nothing bad will happen. You do not have to answer a question if you do not want to. You can refuse to help me even if your parents have said yes.

Talking with me may not help you today. But talking with me will help me and other people better understand how to write programs to tutor children.

As a way of saying thank you, I will give you a small gift after we finish.

If you have any questions about the project, please call me at *xxx-xxx-xxx*. If you want to talk with someone other than me about how you are treated as a helper in this study, you can call the research office at North Carolina A&T State University, xxx-xxx-xxxx. Their job is to look out for kids like you helping researchers. You can also email the office at dheaton@ncat.edu

If you understand what is in this form and want to help in the project, please check the Yes box below, and sign your name on the line below. If not, that's OK – don't check the Yes box or sign your name.

□ Yes, I want to help in the project.

Kid's Signature ____

Researcher's Signature _______________________________________

Date______________________

APPENDIX E

Focus Groups Transcripts

School: Arts Based Elementary School – 3rd grade

Moderator: Have you ever used a tutoring program before?

Red: yes

Green: yes

Violet: yes

Moderator: Do you think the tutoring program helped you?

Green: yes

Violet: yes

Red: yes, I put no I forgot

Moderator: That's ok, you can change your answer if you want to.

Moderator: Now we are talking about a computer tutor like what I just showed you right. What about a human tutor? Have you ever had a person help you as a tutor?

Green: yes

Violet: yes

Red: yes

Moderator: Do you think they helped you?

Green: yes

Violet: yes

Red: yes

Moderator: Okay, so let me ask you some more specific questions about solving problems, okay? For example, if you're trying to solve a problem, right, and somebody just gives you the answer. Do you think that helps you?

Red: no

Green: no

Violet: no

Moderator: Can you tell me why or why not.

Violet: Because you need to learn and do it by yourself. So that no one really te… If someone tells you the answer you don't really get it; or if they do it for you, because you don't know how to do it then.

Moderator: ok. Makes sense.

Green: And I don't think you can really learn like tat because they're doing it for you.

Red: And I don't they could do it because like… they're not like …. Like not like that …good.

Moderator: Now, let's see. What if they were trying to help you, instead of giving you the answer they just gave you a clue? Instead of telling you the whole answer they just gave you a clue to help you along. Do you think that's helpful?

Green: yes

Violet: yes

Red: yeah

Moderator: So you still get to figure it out for yourself they just give you a hint. Okay.
Now let's say you are solving a problem and you make a mistake. Do you think they should tell you right away or wait and let you try to figure out your mistake for yourself.

Green: To let you try to figure it out

Red: or wait until the teacher comes or something

Moderator: So do you think if your tutor is working with you and they see you make a mistake do you want them to tell you right away or do you want them to wait until you find your own mistake.

Red: Find your own mistake

Green: yeah

Moderator: You have some subjects you like and some you don't like right?

Red: yes

Green: yes

Violet: yes

Moderator: Do you think you do better in the ones that you like?

Red: yes

Green: yes

Violet: yes

Moderator: Why do you think you do better in those subjects?

Green: Because you are better at them.

Violet: You listen because you are really interested and you like doing it.

Moderator: okay. That's good.

Red: You like doing it because it's your favorite thing.

Moderator: Okay, do you work harder in those subjects?

Green: yes

Violet: yes

Red: yes

Moderator: Why do you work harder?

Violet: Because you really do want to have it good

Green: Because you want to work hard so you can learn more and get better

Red: Well, if you like that subject then you'll be better at the next subject that your tutor is giving you, like what I was gonna say. I forgot it.

Moderator: Now let's say you had a problem that was really hard, so hard that you didn't even know what to do to solve the problem. What do you think you would do in a situation like that?

Violet: You would raise you hand and ask the teacher for a hint.

Green: You could try figuring it out and if you don't get it you could ask somebody at your table to help

Red: Well you could think about it and solve the problem.

Moderator: So just think a little bit harder about it.

Red: yeah.

Moderator: Now we talked about you using a program before. Can you tell me some types of programs that you used and what was in the programs and how they worked? Did you get them online or did your mother or father buy them for you?

Red: My mom gave it to me, bought it for me
Violet: My mom bought it for me too.
Green: I don't understand the problems
Moderator: You don't understand?
Green: Like what you said.

Moderator: I was asking what kind of programs you used, for example some tutoring programs are like games. It's like playing a game right?

Green: oh, so it's like teachers giving you problems

Violet: At a camp I went to we played games with math

Green: And we have Spanish in the morning with math

Red: Yeah, we do games like Spanish and some other games

Moderator: So some of them the teacher gives them to you like problems to solve and some you play like games.

Moderator: How do you think a tutoring program should help you? What do you think it should do?

Violet: It should help you learn things that you don't know and then you'll be like ohhhh, now I get it.

Green: I think it should help you learn to like focus more on work.

Red: Do the things we just did like pick a color; do the math on the computer, your challenge on the paper, read focus and stuff.

Moderator: So the tutoring program should help you focus.

Red: and do shapes and kind of things

Moderator: So give you images or things like that, graphics. Okay, what else?

Green: I forgot

Moderator: Okay, that's all right now we went through this program. What are some of the features of this program that you remember?

Violet: they had hints

Moderator: What else did it have?

Violet: It just had addition problems

Moderator: Did it have any color in it?

Red: yes

Green: yes

Violet: yes

Moderator: What did the colors mean?

Red: The greens ones mean like good job, and the blue ones mean good job I guess too.

Voilet: and the red ones mean they are wrong

Moderator: So the red ones mean they are wrong and the blue and green ones mean you did good.

Red: yeah.

Moderator: What about the buttons that gave hints? Would you like for tutoring programs to have that button to give you hints if you didn't know what to do?

Red: yes, that awesome

Green: yes

Violet: yes

Moderator: Did you like having the color red so that when the answer is wrong you know that it's wrong and you can take a second look at it?

Red: yeah, oh wait if you get something wrong wouldn't it be awesome if you get something wrong it would be a color that you have. It would be like violet or the same color that I had. I don't know about green though.

Green: yes

Violet: yes

Moderator: So you want more colors to tell you more things about it being wrong.

Red: yeah.

Moderator: Was it clumsy trying to put numbers in the different blocks for the problems? Is there a way to make it easier to do problems on a computer like that?

Red:

Green:

Violet: If you had one number in the box and you got the answer right it would just go on to the next box.

Moderator: So automatically go to the next box that you have to fill in.

Red:

Green:

Violet: yes

Moderator: That makes sense. Let's see. We didn't get a chance to look at all the features of the program, but one thing that the program does it that if you get the wrong answer in one column it won't stop you. You can still go to the next column and put in an answer. Do you think that's good or should the program stop you and not let you go on if the answer is wrong?

Red: That's good.

Green: I think it' good

Violet: That's good.

Moderator: Do you think that it's good that it lets you go on and doesn't tell you; lets you figure things out for yourself, or should it just tell you that you're wrong and not let you go on?

Violet: When you go to the end it should have like a buzzing sound. Then you can go back and change your answer.

Moderator: So instead of telling you that it's wrong it give you like a sound?

Violet: yes.

Moderator: Was there anything else you wanted to discuss about the program or about tutoring programs in general? First we'll talk about the program them we'll talk about human tutors a little bit. Then we'll wrap it up for today, okay.

Moderator: For tutoring programs what other things would you like for the programs to do or where would you like to be able to use the programs?

Violet: I would like to be able to use it at home.

Moderator: Where else would you like to be able to use it.

Green: I would like to be able to use it at school

Moderator: Are there any other features you would like to see in programs? Any things that programs don't do that you would like for them to do?

Violet: Spelling

Red: Spelling yeah.
Violet: Yes where it give you a sentence with mistakes and you have to fix the mistakes

Moderator: So you want different types of subjects other than math.

Violet: yes
Green: I like the games in the computer lab that you have to keep typing, but if you get it wrong it turns red but you have to keep going, then it will tell you the score at the end. You get different levels and worlds to go through.

Red: Oh yeah that's right

Moderator: Different levels, different scores

Violet: and worlds to go through

Green: You can play games on it too, but no typing.

Moderator: Did you want to say something Red?

Red: Well Sometimes at my mom's house when we come back from school my mom let's me do some math games, like where we sort money and like you pretend you are just riding in the car on the road to get to the next level you have to you have to do what is like that plus that or that times that.

Moderator: So you have to play and get that right before you get to the next level. Okay.

Moderator: Anything else on the computer tutors?

Green: It would be cool if you could take it on your laptop if you were traveling somewhere if you had a long ride.

Moderator: Okay, how about human tutors; people who help you? What would you like to see people do to help you more?

Green: Maybe give you something like a treat after you did it.

Moderator: Ok. A reward after you do your tutoring work? Antthing else?

Violet: If you are doing it with a group and if you can't get it give them a hint, because last year I had that and we could get it and we didn't get any hints and the teacher just told us the answer.

Moderator: I see, so when you are working with a group and none of you could get it, she didn't give you any hints she just gave you the answer, but you would rather get a hint so that you can figure it out.

Moderator: Green did you have something you wanted to say?

Green: no

Moderator: I won't keep you. You have been great kids and so if you don't have anything more we will wrap up for today. I really appreciate your help on this project. I hope that we can develop better software and better teaching procedures to help students.

School: Carter G Woodson School of Challenge – 3rd grade

Violet
Fuchsia
Blue
Red
Gold

These same questions were asked of all students.

1. **Have you ever used a tutoring program before?**
2. **Have you ever had a human tutor?**
3. **Do you think they were able to help you?**
4. **What do you think they did that helped you?**

Violet: no
Violet: yes
Violet: yes
Violet: They helped me with things that I didn't know about.
They helped me with math and reading

Blue: no
Blue: no

Fuchsia: no
Fuchsia: yes
Fucshia: yes
Fuchsia: They helped by teaching me a grade level above what I can, and things I didn't know about and how to do them and the easy way rather than doing it the hard way.

Red: no
Red: yes
Red: yes
Red: They gave me all the help they can give me.
Do you mean the time the put in to help you?
Red: yes

Gold: no
Gold: yes
Gold: yes
Gold: They helped me to be a better student.

Let's say you were trying to work on a problem and someone came gave you the answer. Do you thing that would help you?

Unanimous: no

Why not?
They all tried to talk at once.
Blue: If someone tells you the answer they are not helping you they are just telling you the answer. They are just cheating.
Fuchsia: It would be cheating because if you want to pass the grade an you don't know it and you are trying to figure it out it is not going to help. If you are trying to pass the EOG It is not going to help because someone is not going to give you the answer on the EOG.
Violet: You are not going to be able to learn because they are telling you. They are not helping you
Red: It is not helping because when you try to get the answer and you ask can you help me and they tell you the answer. It's not fair because they already know the answer you don't and you want to figure it out yourself.
Gold: It's not good because someone might tell you the answer and they might tell you the wrong answer and they might put you back in the same grade you are right now.
Violet: They are going to tell you the wrong answer and you are going to put it down and get retained.

Suppose instead of telling you the answer they just gave you a little hint to try to help you figure it out for yourself. Do you think that's better?

Fuchsia: It would be much better as long as they don't give you the answer they can give you a hint and you can find the answer for yourself.

Gold: It is right because they'll give you a hint and you won't be retained. The computer program gave you hints and that helped.

Violet: Sometimes when they give you a hint it can be to close to the answer. You can just get the answer.

Red: It is not fair because they are going to give you a hint and you have to show the answer and you are not going to know how to show the answer. You can write the answer down and make one hint.

Blue: If you give a little hint the person would be able to figure out the answer. But, just a little, teeny hint, not a big hint.

Violet: You want to figure out the problem by yourself and they just give you a little hint. If they give you too much of a hint now you got the answer and your teacher thinks you cheated.

Red: They gave you too much of a hint you are not going to be able to show the answer. You can go right to the answer.

Fuchsia: If they give you a hint that is not close to the answer but a little close to the answer it can be all right because if the teacher ask you how you got the answer and you don't know she'll say you don't know how to get the answer in her notes.

Let's talk about the program.
What did the red letters mean?

Unamious: wrong answer

What did the blue and green letters mean?

Unamious: correct
Green means correct and blue means almost correct or hint.

If you didn't know what to do, what could you do with the program?

Unamious: hint

Fuchsia: and you follow the instructions where it say give a hint.

Blue: same thing she said

Violet: the same thing she was saying

There are some subjects in school that you like and some that you don't like. Do you do better in subjects that you like?

Blue: Like
Violet: Like and sometime in ones I don like
Red: Both

Is there anything that makes you do better in some subjects and not so well in others?

Blue: It makes me do good in math but not in reading, and in science but not in social studies.

Why do you think you are good in some things but not other things?

Fuchsia: You can be good in one thing an have this other thing where you say you're not good all you have to do is try and you can get better at it.

Violet: Practice makes perfect. You haven't tried the next subject so you don't know how to do it yet.

Do you think that you always do better in subjects if you work harder?

Unanimous: yes

Are there some subjects you work hard in but still don't do well in?

Unanimous: yes

Are some subjects more boring than others?

Unanimous: no

What kind of computer programs have you used before?

Various responses
What do you thing a tutoring program should do to help you?

Fuchsia: I think it should teach you more about what it is teaching you but give you more information.

Blue: It should teach you more things like some things that you already know and some things that you don't know and information and they should teach you about all of the subjects.

Violet: They should show you division and multiplication and things that you don't know so that you can do better in the grades and do math worksheets and things.

Gold: It will help reading class but you'll still have to find your answer from the reading.

Red: It should show you things that you already know and things that you don't know.

Is there any thing you want to say about tutoring or tutoring systems?

Unrelated questions and comments
Some wanted expanded tutoring topics

School: Carter G Woodson School of Challenge – 3rd grade – Group 2

Red:
Indigo:
Green:
Silver
Gold:
Gray:

These same questions were asked of all students.

5. **Have you ever used a tutoring program before?**
6. **Have you ever had a human tutor?**
7. **Do you think they were able to help you?**
8. **What do you think they did that helped you?**

1.
Green: Yes, it helped me with sound. Different kind of animals, Low noise and High noise. I got all of them right.
Silver: Yes, it made me get good grades.
Gold: Yes, it helped me with a lot of stuff: math, reading and science.
2.

Red: My mom helped me but she didn't really help me. My uncle helped but he didn't really help me he just gave me the answer.
Indigo: No
Silver: Yes, They gave me hints
Green: They help me with nines. They helped me with how to count. If we learned a lot we got tokens to buy stuff from the big wall. I did 4th grade math when I was in second grade.
Gold: Well not really. I got help with my homework from my mom.

If you were trying to solve a problem and someone saw you were trying to solve the problem and gave you the answer. Do you think that helped you?

Unamious: no

Green: I am not learning anything if they just tell me the answer because when I take the EOG they won't be there to help me.
Indigo: Well kind of helpful but I wouldn't learn unless they sit down and teach me and ease me through the way to get the answer.
Gray: No they just gave you the answer.
Red: No, I don't think it is helpful because if you gave me the answer I haven't done anything and I won't be helped. You won't be here to help in school or in college.

Every seemed tired and so I let them stand up to stretch.

What if you were trying to solve a problem and someone saw you were trying to solve the problem but instead of giving you the answer they just gave you a hint?
Red: That would be helpful. Then after you try to solve the problem and they came to check on you and they said it wasn't right and then you would get it right because you did it all over. Then if you more problems you will get them all right.
Green: I think that would be helpful because, they are trying to give a little hint so that you can get the problem right all on your own. So you can learn how to do the same question on the EOG or another quiz that you might take.
Indigo: You might have got it right. It might be kind of helpful and kind of not helpful.
(it depends on the hint they give you)
Gray: A hint is better because it is not giving you the answer but it is helping you get the answer, in a different way.
Silver: no answer

Let's talk about the program on the computer.
When you saw red letters what did that mean?

Answer: Wrong

They also knew what green meant. Blue confused some.

What other features did the program have?

Answer: Hint

Answer: new problem

Do you have some subjects that are hard or easy? Do you like the easy ones or the hard ones better?

Some said hard. Some said Easy.

Red: It had levels. When I got to level 12 I thought maybe it was too hard and I might get it wrong.

Green: I catch onto hard problems quickly.

Suppose you had a problem that was really hard and you couldn't solve it. What would be the first thing that you would do?

Red: I would raise my hand and ask the teacher to help me. She might help or give me a calculator.

Indigo: I would read it and if I couldn't solve it ask someone to help me.

Green: I would if it were really, really hard, ask three other students for help ask the teacher. If it's in a math book it says go to the gallery to see what it means.

Silver: I would draw a picture and I would write the answer down.
Gray: I would draw circles and count. I would ask others for help.

What features does a tutoring program need to be a good tutoring program?

Red: Hardware

Indigo: Explanation

Blue: More types of problems

Say anything you want ideas, suggestions:

Gold: color, worksheets, printers
Red: Math, reading Science, adding, all the grades, tutors
Green:
Indigo: Ask their opinions and see what they need.
Silver: