THREE CASE-STUDIES OF THE USE OF AN AUDIO SUPPORT SYSTEM EMBEDDED IN A COMPUTER-BASED COGNITIVE TUTORING SYSTEM AND ITS EFFECTS ON THE MATH WORD PROBLEM SOLVING PERFORMANCE OF STRUGGLING READERS

by

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Submitted to the Graduate Faculty of

Education in partial fulfillment

of the requirements for the degree of

Ed.D. in Reading

University of Pittsburgh

2008

UNIVERSITY OF PITTSBURGH

FACULTY OF INSTRUCTION AND LEARNING

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December 10, 2008

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The purpose of this multiple-case study was to investigate the importance of the use of a support system in which the math text is read to the students through the use of a text to speech engine (audio support system) embedded in a cognitive tutoring system. In addition this study investigated whether the use of an audio support system had any effect on the word problem solving performance of three struggling readers when they were presented with a seven-step process to solve word problems. Pre-assessments were carried out to determine whether the participants had reading difficulties in the areas of decoding, fluency and/or comprehension that may affect their math word problem solving performance. The results indicated that the embedded devices did facilitate the word problem solving skills of these struggling readers. The reading barriers were reduced or removed and the program allowed for individualization. The results also indicated that the participants utilized these embedded devices differently; however, there was not a significant difference comparatively in how these devices were used. Whether the students were successful in learning from this cognitive tutoring system is inconclusive. This program is written in such a way that the students are expected to solve the word problems correctly because the embedded devices made it almost impossible for the students to fail. Although the cognitive tutoring system appears to be an effective approach for providing ongoing practice and individualization, it appears that students would benefit from direct instruction from the classroom teacher who can help the students review their work, identify their own mistakes, make the necessary corrections, and bring about a more thorough understanding of the problem solving process.

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ACKNOWLEDGEMENTS

At this time I would like to thank the people who guided and supported me throughout this process. First I would like to thank my best friend Pat who walked beside me on this path enduring the challenges and celebrating this accomplishment with me. Second I would like to thank my committee members Dr. Linda Kucan, Dr. Ellen Ansell, Dr. Rebecca Hamilton, Dr. Naomi Zigmond, and my advisor Dr. Rita M. Bean for their time, their expertise and their guidance throughout this unforgettable experience.

1.0 INTRODUCTION

Struggling readers repeatedly present a dilemma to educators of content area curriculum because the reading of content area text usually involves unfamiliar vocabulary and complex reading material. These struggling readers often have deficiencies in one or more areas, e.g., decoding, fluency or comprehension. Deficiencies in word recognition and fluency can create an even greater problem when struggling readers encounter math word problems, given the likelihood of a greater preponderance of complex vocabulary words. Even though students may have acquired the necessary computation skills for math success, being able to accurately decode unfamiliar words and read with adequate fluency are essential to successful comprehension and successfully solving math word problems.

Thus, one of the major and perhaps underestimated problems of struggling readers in solving word problems is their poor decoding skills and inadequate fluency--especially when they do not exhibit any deficiencies in computation skills. By reducing the burden of inadequate word recognition and inadequate fluency of many struggling readers through the use of an audio support system, many struggling readers may be more successful at solving math word problems. According to McCandliss, Beck, Sandack, and Perfetti, (2003) reading is a combination of decoding and general language comprehension and there is a correlation between skilled decoding and comprehension abilities.

Reading is an integral component of everyday life and being literate has become a necessity in today's society. It is no longer considered acceptable to have students graduating with limited literacy skills. Exposing students to books is an important aspect of promoting literacy, but it is not enough. Students need to be taught how to read (Moats, 2000). An assumption that teaching students to read is the responsibility of the language arts teacher can no longer be accepted if students are to become literate in the content areas. Educators who teach the content areas are the ones who know and understand the language of their specific content area the best. Moats (2000, p.5) states that, “the choice of instruction should be based on awareness of the student and the content at hand”. Content area literacy can be defined as the levels of skills necessary to read and comprehend instructional materials in a given subject area (Readence, Bean & Baldwin, 2001).

What impact if any does this have on struggling readers with regard to math instruction? Adams and Lowery (2007) describe reading in the content of mathematics as being a complex presentation because students are required to read numerals, symbols and diagrams as well as the words of the text. Comprehension of the text means that students not only understand the written text but also the vocabulary of mathematics. Since content-area literacy includes the incorporation of strategies and skills generally addressed in language arts classes, many content area teachers tend to focus on the content itself rather than the reading. Yet, focusing on reading in the content area is imperative since readers of content encounter unfamiliar vocabulary and more complex reading material. Further, the National Council of Teachers of English (NCTE) actively supports the incorporation of reading strategies in other content subject areas. The NCTE (n.d.) states that “No matter what the subject, the people who read it, write it, and talk it are the ones who learn it the best” (as cited on NCTE website: Language), but research has shown that it is often difficult to incorporate reading instruction into mathematics (Borasi, Siegel, Fonzi, & Smith, 1998; Draper, 2002).

1.1 THEORETICAL PERSPECTIVES

According to Hoover and Gough (1990), reading is merely the product of decoding and linguistic comprehension. Reading deficiencies can then be explained as the absence of word recognition or the understanding of language. If a child lacks the ability to recognize words in text, then their comprehension of what they have read suffers. Similarly if the student is able to recognize words but has not developed an understanding of the language and vocabulary, comprehension will not take place (Gough, 1996).

However, Goodman has taken a different approach on reading acquisition. His belief is that, in reading, the reader constructs a text that is parallel to the published text (Goodman, 1992). This parallel text includes the readers' values, beliefs, prior knowledge and experiences. Goodman's model constitutes a holistic approach to reading known as whole language. Classroom environments are developed to meet the needs of the children and good readers can make meaning of what they read.

How then are struggling readers affected by these theories with regard to math content area literacy? In the past, researchers have attempted to discern precisely what barriers students' encounter in the process of solving mathematical word problems that prohibit them from converting the words into meaningful representations. A generalization among these researchers is that this may be directly related to a lack of mathematical problem solving skills, and that students need to be taught the appropriate strategies. Once educators teach students those math problem solving strategies, the students will be able to plan and execute the correct mathematical operation to successfully solve the math problem. Teaching students how to use math problem solving strategies will assist them in building math computational skills, however it will have no effect on their ability to read the math word problems. Students need to be taught how to use reading strategies in the math content area.

Kane, Byrne, and Hater (1974) considered reading to be a quiet form of speaking in which students translate the written words of text and comprehend the meaning. According to Thompson and Chappell (2007), students struggle with the reading of mathematical word problems because they do not have a complete understanding of the vocabulary of math. In other words they can translate the words but are not able to comprehend their meanings. These comprehension skills are essential for solving word problems. By utilizing instructional practices in the math classroom that include the use of reading strategies, educators can lesson the frustration felt by these students.

On the other hand, Adams (2003) explained that mathematical reading involves the utilization of decoding, linguistic comprehension, and the knowledge of the "language of mathematics" which includes words, numbers and symbols. In other words, it is not merely the reading of the words that is required but an awareness of what those words represent within the context of the problem and the ability to process the content to construct a meaningful representation. Reading requires students to activate prior knowledge. Anderson and Pearson

(1984) have demonstrated through research that the activation of prior knowledge is imperative for the comprehension of text. If students lack prior knowledge it could subsequently impact how they solve word problems presented in the text. According to Aiken (1972), there is a strong correlation between reading comprehension and math problem solving abilities and that students who have highly developed comprehension strategies have a propensity to do extremely well when solving math word problems.

Researchers have differing views on whether solving word problems successfully can be linked to a decoding or comprehension deficiency. For that reason, this study is based on the assumption that struggling readers are limited by their inabilities to decode or comprehend the language of mathematical word problems. These limitations can restrict the cognitive growth of students because they lack the necessary skills required to decipher the language of mathematics.

1.2 PURPOSE OF STUDY

The purpose of this multiple-case study was to investigate the importance of the use of a support system in which the math text is read to the students through the use of a text to speech engine (audio support system) embedded in a cognitive tutoring system. This multiple-case study investigated whether the use of the audio support system had any effect on the word problem solving abilities of struggling readers when they were presented with a seven-step scaffolded process to solve word problems. It also attempted to explain whether the use of the audio support system was essential to the achievement of the students who were identified with differential reading difficulties, specifically decoding and fluency which can ultimately result in comprehension difficulties. Another important aspect investigated by this multiple-case study was whether there were significant differences in how the embedded devices were utilized by the individual students and how successful the students were in learning from this cognitive tutoring system.

However, the main focus of this multiple-case study was to examine the differences in the word problem solving scores of the individual students who were previously identified as having existing decoding, fluency, or comprehension difficulties. Finally, this investigation explored what differences were presented in the student's performances when the pre and post math word problems tests were read to the students compared to when the students read and completed the items individually.

1.3 RESEARCH QUESTIONS

The questions are:

1. In what ways did the use of an audio support system and other learning devices embedded in this cognitive tutoring system facilitate the word problem solving skills of struggling readers?

2. Were there differences in how these devices were utilized by the individuals who were identified as having existing decoding, fluency or comprehension difficulties?

3. What differences were there in the students' performance when the pre and post math word problem tests were read to them as compared to when the students read the test items themselves?

4. How successful were the students in learning from this cognitive tutoring system?

1.4 DELIMITATIONS

The intent of this multiple-case study was to provide information regarding the use of an audio support system embedded in a cognitive tutoring system and utilized by struggling readers. The results of this investigation can not be generalized to all cognitive tutoring systems that utilize a text to speech engine. Furthermore, this study did not attempt to study other types of cognitive tutoring systems, or to see if they are more effective than a live teacher in the education of struggling readers.

Another delimitation of the study was the length of the study. This study was conducted over a period of eight tutoring sessions during a three month period with each session lasting approximately sixty minutes.

1.5 DEFINITION OF TERMS

COGNITIVE TUTORING SYSTEM- A computer program that emulates human tutors by providing individualized instruction to students.

LEVELS- A progression from the least difficult problems to the most difficult problems.

SCAFFOLDING- A temporary support system used by teachers to link student achievement with a given task. (Papala & Olds, 1998)

TALKING AVATAR- An animated human form utilized in this computer program to assist students when they are having difficulty reading the text of the word problem. The avatar reads the word problem aloud to the student through the use of an audio support system.

TEXT TO SPEECH ENGINE- An audio support system that utilizes a talking avatar.

2.0 LITERATURE REVIEW

This chapter focuses on the literature reviewed for this study. The introduction addresses the connection between fluency and comprehension. The second section addresses factors that affect reading success. In the third section expository text is discussed. The fourth section discusses math problem solving studies, some that utilized reading strategies and others that utilized math strategies. The fifth section discusses research on cognitive tutoring systems. The final section summarizes the entire chapter.

2.1 INTRODUCTION

The transition from "learning to read" to "reading to learn" often begins in the third grade. Often times students who have not attained mastery of the requirements of reading by this grade level are not presented with opportunities to enhance these skills (Gunn, Biglan, Smolkowksi, & Ary, 2000). Students who have poor decoding skills are less likely to be able to focus on comprehending what they are reading because they focus on decoding the words. Research has shown that reading is a process of developing adequate skills in phonological awareness, decoding, fluency and comprehension. It is the combination of these skills that affect a child's reading ability and children may have weaknesses or strengths in one or more of these areas.

A meta-analysis of research studies conducted by the National Reading Panel (2000) indicated that children who were exposed to systematic phonics instruction in the first grade were better able to decode and their ability to comprehend text was significantly improved. However, older children who were given the systematic phonics instruction demonstrated improved decoding skills but no significant evidence of improved text comprehension was observed. Research has shown that systematic phonics instruction increases a child's decoding and word recognition skills, facilitating comprehension of text.

Oral reading fluency is the ability to read aloud text with accuracy and speed. Fluency plays an important role in the comprehension of text. Comprehension deals with constructing meaning from what is read more than from recalling what was read. Children who struggle to read fluently have difficulty in remembering the text that they read. Recent research on the efficacy of certain approaches to teaching fluency has led to increased recognition of its importance in the classroom and to changes in instructional practices.

Comprehension is critically important to the development of children's reading skills and therefore to the ability to obtain an education. In the meta-analysis of research conducted by the NRP (2000), three predominant themes were presented on the development of reading comprehension skills. First, reading comprehension is a complex cognitive process that cannot be understood without a clear description of the role that vocabulary instruction and development play in the understanding of what has been read. Secondly, comprehension is an active process that requires intentional and thoughtful interactions between the reader and the text. Third, the preparation of teachers to better equip students to develop and apply reading comprehension strategies to enhance understanding is ultimately linked to the child's achievement in this area.

2.2 FACTORS THAT AFFECT READING SUCCESS

Phonemic awareness has been linked with word recognition and reading development. Furthermore, oral vocabulary and listening comprehension are factors that affect comprehension of text. Reading is reliant on the development of many levels of language skills. A cognitive model of reading known as the Simple View of Reading provided the framework for a study conducted by Konold, Juel, McKinnon, and Deffes, (2003) in which the relationships between the components involved in decoding, listening comprehension, short-term memory and processing speed provided more insight into the cognitive functions involved in reading acquisition. In this study one thousand six hundred and four children were selected from the standardization sample used for the Woodcock Diagnostic Reading Battery. These children ranged in ages from 5 to 10 years of age. Four reading outcomes were used to measure auditory processing, comprehension ability, processing speed, and short-term memory. The children were categorized as following: average reading ability, below-average reading ability, average reading ability with strengths in comprehension knowledge and short-term memory, above-average reading ability, average reading ability with strengths in auditory processing, and average reading ability with elevated processing speed. The results of this study revealed that children with average reading ability and strengths in auditory processing performed better than the students profiled as average reading ability without strengths in auditory processing. The study also found that processing speed is an important predictor of reading success in the early years. Comprehension knowledge and short-term memory were found to only be a partial contributing factor in children of average reading ability who had strengths in both these areas. Results of this study indicate that reading acquisition is a product of oral vocabulary, listening comprehension, decoding and processing speed.

Fluency is one of several critical factors necessary for reading comprehension. However, it is often not included in classroom instruction. Children who struggle to read text, given their focus on decoding, often have difficulty in remembering what they have read and relating the ideas to their background knowledge. Rasinski (1990), conducted a study where the methods of repeated readings and listening-while-reading were utilized. This study used twenty third grade students who were required to practice reading one passage independently, and read another silently while listening to the teacher read fluently. Students were divided into high, average, and low reading ability level groups. The study found that both the repeated readings and listening-while-reading methods were effective in improving the fluency skills of the students.

Perfetti (1985, p.11), concluded that fluency and comprehension are closely linked characteristics of reading skills. However, although fluency can affect comprehension, comprehension does not affect fluency. In a study conducted by Shinn, Good, Knutson, Tilly and Collins (1992), the relationship between Curriculum-Based Measurement (CBM) oral reading fluency and the reading process was examined. This study used 114 third graders and 124 fifth graders. Students were assessed on tasks requiring decoding, comprehension and fluency skills. Assessments were administered individually and in groups. The study concluded that fluency and comprehension are important factors in measuring reading proficiency. Results for the third grade indicated a higher correlation between the CBM measures where the students read aloud compared to the conventional inferential and literal comprehension measures. In the results for the fifth grade it was noted that decoding and comprehension were highly correlated. Conclusions drawn from this study indicated that CBM oral reading fluency is a valid measurement of reading ability.

According to Beck, Sandak and Perfetti (2003), increasing decoding skills in children does not mean that those children will be able to transfer those skills to text comprehension. Often-times classroom instruction focuses on the skill of decoding words without the use of connected text. Reading instruction should include decodable text so that children can benefit from the learning experience. The study by Beck et al. used 38 children ranging in ages from 7 to 10 years old. Attrition reduced the group sizes to 24 students. This study utilized a word building intervention in which the students were required to create an initial word from letter cards and then replace one letter card with a new letter card to form a new word. The results after 20 intervention sessions showed that the intervention group had gains in decoding, phonemic awareness, and passage comprehension. Although there was no evidence that the gains in comprehension were related to any particular portion of the intervention it does appear that there is a link between the gains in decoding to the gains in comprehension.

The importance of systematic phonics instruction, vocabulary instruction and text comprehension instruction are included in the meta-analysis of the research presented by the NRP (2000). But the question remains- might the listening to text both relieve the burden of decoding and strengthen the potential for comprehending? According to Gough and Juel (1991) and Stanovich (1991) listening comprehension is a pathway to understanding for children. Thus, reading comprehension is equal to listening comprehension plus decoding. If the decoding barrier is removed, listening comprehension can then be regarded as a representation of a child's true comprehension capabilities. In a study conducted by Tindal, Heath, Hollenbeck, Almond, and Harniss, (1998), teachers orally read the math standardized tests to students with disabilities. The two specific test accommodations used in this study were; a response (marking format) and a presentation accommodation. The study consisted of a total of 481 students, 403 general education students and 78 special education students. However, the presentation accommodation was only investigated using the math standardized test portion of the study and was given to a subgroup that consisted of 198 low-achieving general education students and 38 special education students. Some of the students in this subgroup read the test silently to themselves, while the others in the subgroup listened as the teacher read aloud the test in its entirety. The results demonstrated that the special education students with IEP's in reading and math performed significantly higher when the math test was read aloud to the students by the teachers when compared to their peers who read the test silently to themselves. However, no significant differences were noted for the general education students with the same accommodations.

2.3 EXPOSITORY TEXT

Elementary students are generally exposed to more narrative texts than they are to expository texts. This is primarily due to the fact that parents and elementary teachers often read narratives or trade books to students. The stories found in narratives are engaging and often times entertaining. The opposite is true for most expository text since the main purpose of expository text is to convey information. Such texts may also contain different structural patterns than narratives due to the fact that the organization of ideas and the relationship of those ideas communicate meaning related to a specific topic relative to the expository text in question. (Meyer & Rice, 1984).

Comprehension of expository text may be more difficult for students because they lack the knowledge of text structure that is required for comprehension to take place. (Oakhill & Yuill, 1996). Narratives often depict a sequence of events that may be familiar to students, or can activate their prior knowledge to support comprehension. However, expository text tends to require a student to use higher order thinking skills without the assistance of prior knowledge. Wolfe (2005) found that when students comprehend and recall a text they rely on both prior knowledge and the text itself. Students whose prior knowledge is limited may have difficulty in comprehending the text. The information that the students bring to the task of reading the expository text may not be adequate enough to permit understanding. (Beck & McKeown, 1989).

Struggling readers can find it exceptionally difficult to read expository text. They tend to have limited vocabularies when compared to proficient readers. Expository text is more apt to contain fewer high-frequency words than narrative text and a more technical vocabulary related to the content area (Carnine & Silbert, 1979). Comprehension of the text is dependent upon the reader's ability to make the connections within the text and for struggling readers this can be a very frustrating task.

2.4 READING IN MATHEMATICS

The development of strong reading skills is necessary for success in the content areas. Readence, et.al. (2000), describe the focus of content area literacy instruction as reading to learn, not learning to read. Reading in the mathematics classroom can prove to be very challenging for struggling readers. The linguistic aspects of mathematics can be different from other content areas in that the symbolic representations and visual images used may not correspond with the translation of those representations. (Schleppegrell, 2007).

Readers need to understand the text of the word problems and be able to use that to complete some form of mathematical action (Adams, et al., 2007). Math textbook writers generally focus on the mathematical skill to be applied. This can prove to be challenging for struggling readers when definitions of terms take on a different meaning in math than they do in the reading classroom. Standardized assessments have become increasingly challenging for struggling readers because they are required to not only be able to read but also comprehend the text to demonstrate mathematical literacy. Reading of mathematics text becomes increasingly difficult for struggling readers because they have not developed the skills necessary to make the transition from narrative to expository text.

2.4.1 Using Reading Strategies in Math

According to Carter and Dean, (2006), teachers need to incorporate effective reading strategies into the mathematics classroom because students are required to read much more intense material with more technical vocabulary. The purpose of the study they conducted was to examine whether mathematics teachers used reading strategies in their lessons to help students understand math concepts. This study took place at a clinic at a large university and students attended four days a week for three weeks. There were eight instructors who were also graduate students at the university and fourteen students. Analysis of reading strategies in the lessons was conducted without the knowledge of the instructors. Audio tapes were used for data collection. The researchers were attempting to discern if decoding, vocabulary and comprehension strategies were being used. The results of the data analysis indicated that there were 101 separate cases of instruction using decoding, vocabulary, and comprehension strategies, with decoding occurring less often than the others. Seventy of the 101 cases were vocabulary instruction, with only 29 instances of comprehension strategies.

A limitation of this study was that it was conducted in a clinic setting where students normally receive more one on one instruction than they would in a regular classroom. Another limitation that could be noted is that there were eight instructors for only fourteen students. Even in a clinic situation the reading strategy that was observed the most was vocabulary instruction. Although the students were assessed for math deficiencies prior to instruction none of them were assessed for reading deficiencies.

Mitchell (2001), contends that students tend to solve math word problems by forming and manipulating representations of the problems. In 2001, she conducted a study to determine how students solve word problems. Her study involved 31 seventh grade students. She created the phrase “wordwalking” to represent the substitutions that the students made of a word or phrase in the word problem. Students were pulled from their regular classes for this study. Both an independent, think aloud format and a paired student format were utilized. There were 124 think-aloud protocols with each student completing four problems. In the independent think aloud format the student would read the problem and complete it independently. In the paired format one student would read the problem and then present it to a second student, where they would work out the word problem together. The student sessions were videotaped for data analysis and inferences were drawn by the researcher with regard to student interpretations of the word problem. The researcher found that she had insufficient data to determine how or when “wordwalking” happened. The researcher found that the students tended to substitute words when a word meaning was unclear to them. This is not unlike what struggling readers do when reading a passage.

There were many limitations to this study. The researcher used videotapes of the sessions with the students and coded them based on attempts and elements. The researcher then made inferences based on what she thought the students meant or were thinking at the time of the “wordwalking” event. It was unclear as to how long this study lasted. The students were not pre-assessed for any deficiencies prior to implementing the study. The rationale for the study was unclear as were implications for any future studies of this nature.

The strategy of oral retelling was utilized in a study by Monroe, Black, and Buhler, (2002). In this study the researchers designed a 15 lesson instructional sequence to be used by a third grade teacher that would help students learn to solve word problems using oral retellings. The study lasted approximately four months with the lessons being taught intermittently. The lessons lasted for approximately thirty minutes and involved ten students. These students were interviewed pre and post the lesson sequence and also videotaped during lessons. The teacher drew the word problems for focus lessons from a bank of word problems created by the researchers. Oral retellings for this group of students included repeating the word problem word for word and retelling the numbers and context of the problem. Data analysis of the interview sessions demonstrated that the students were more comfortable with oral retelling in their own way and not as had been anticipated by the researchers. The researchers found that the students in this study generally were more successful at solving word problems using more difficult numbers.

A possible limitation of this study was the time frame. There was no consistency as to when the students were taught 15 lessons involving oral retelling over a four month period. It was unclear as to whether the students had been taught the strategy of oral retelling prior to the study. The rationale for the study was not apparent and no purpose was presented in the paper. This study involved one classroom with ten students. The results may have been considerably different had the researchers conducted the study within several classrooms, and over a shorter period of time with some consistency in the lessons.

According to Capraro and Joffrion (2006), mathematical content reading requires that students understand the meanings of words. These words are not usually part of the students’ normal vocabulary or they may have different meanings from words students already know when applied in the math classroom. They conducted a study that included 668 middle school students in 25 classrooms. One purpose of this study was to examine factors that may be affecting student learning. Pre/post assessments utilizing two parallel forms of the algebra test were given, 7 multiple choice, 7 short answer and 1 extended answer. The researchers examined three specific posttest tasks, two multiple choice and one short answer question to see how the students translated the words into algebraic equations. They then randomly chose 60 incorrect responses and of those randomly chose 5 students to interview in a cognitive lab. These students were directed to use the think aloud strategy to explain their reasoning for their answers. Field notes were taken of these think aloud sessions and then analyzed by the researchers. Their results yielded a more complete understanding of how students think and reason when translating mathematical words to symbols. The researchers found that vocabulary plays an important role in understanding mathematics and that reading in mathematics requires the student to understand the words.

Although the study was conducted using 668 students, the researchers chose to use only 60 randomly chosen students with incorrect answers to 2 of the multiple choice questions and 1 short answer question. The researchers felt that these questions were the questions that required the students to translate the words into algebraic equations using the richest language. It is unclear as to why the researchers chose to have only five of the sixty randomly chosen students use the think aloud strategy to explain their reasoning for their chosen answers. There was no background information supplied that would give an insight into the math or reading abilities of these five students. The sample of five students seems rather small to discern whether the students could not successfully translate the vocabulary into an algebraic equation.

2.4.2 Mathematical strategies

In a study conducted by Jitendra, Griffen, McGoey, Gardill, Bhat, and Riley (1998) two different approaches were used to investigate how specific math strategies affected the problem-solving abilities of students with mild disabilities and those who were at risk. These two strategies were the schema based strategy and the traditional basal strategy. In the schema based strategy the students were given an explicit procedure to utilize in solving the problem. In other words, they were given the tools needed to sort problems into groups that required the same problem solving skills. The traditional basal strategy, used in most textbooks, is a guided discovery strategy and is generally used to solve all types of word problems (i.e. read the problem, plan, organize, and solve the problem).

The sample for this study consisted of thirty-four students from grades 2, 3, 4, and 5 who were identified by their teachers as possessing the ability to compute addition and subtraction problems, but unable to solve word problems. The students had to meet three criteria to be included in the study. They had to achieve 90% accuracy on a simple computational test that consisted of only addition and subtraction problems. They also were required to solve simple action problems (i.e. Billy has two baseballs, his uncle gives him two more, how many baseballs does he have in all?) with a 90% accuracy. Finally they had to score 60% or less on the fifteen word problem test that was administered. The researchers used a comparison group that consisted of 24 normally achieving third grade students as their normative sample. This study was conducted for twenty-three days.

The researchers found that the students who were provided with the schema based strategy scored higher on the post test, on the story problems, than those who used the traditional basal strategy, and that those students with mild disabilities benefited from this approach. According to the researchers these findings suggest that using a schema based approach with students with mild disabilities benefited them more than the traditional basal approach.

Fuchs, Fuchs, Prentice, Burch, Hamlett, Owen, Hosp, and Jancek (2003), conducted a study in which the researchers wanted to assess the effects of explicitly teaching for transfer by utilizing a transfer plus solution instructional method. To explicitly teach for transfer means to teach children to master problem solving rules, sort problems into categories requiring the same mathematical skills, and to recognize related problems or to transfer skills from one problem to the next. Explicitly teaching for transfer requires higher order thinking skills because it takes students from the concrete to the abstract.

The sample for this study included twenty-four third grade teachers and three hundred seventy-five students and was conducted over a period of sixteen weeks. The researchers used pre and post tests for their assessments. The study was conducted using three experimental conditions: explicit instruction, intense practice of examples, and peer-mediated practice.

In this study, the researchers found that only the students who were present in all the solution sessions improved and that the students with disabilities did not improve as well as the researchers expected. Teaching for transfer facilitates mathematical problem solving when students can use problem solving rules, sort the problems into similar categories, and then transfer the skills needed to solve these mathematical problems from one problem to the next.

When students can recognize that problems are familiar and require the same solution methods, metacognition increases.

In a study conducted by Jitendra, Hoff, and Beck (1999), the researchers were attempting to ascertain if using a schema strategy affected the progress from solving one-step word problems to solving two-step word problems in students with learning disabilities and also the effects of maintaining the strategy over time. The schema strategy consisted of three areas of knowledge needed to be successful in completing word problems. These three areas of knowledge are: problem schema, action schema, and strategic knowledge. Problem schema emphasized identifying specific features of the problem such as grouping, comparing and changing. The action schema entailed identifying the solution strategy to be used, and strategic knowledge meant executing the correct mathematical operation.

The sample chosen for this study consisted of four middle school students all of whom were selected because they met the Pennsylvania state criteria for learning disabilities and were placed in learning support classrooms. In addition to the above criteria, the students also had to meet the criteria required of the researchers. They were all identified as poor word problem solvers. Each student completed a simple addition and subtraction computation test with and without regrouping, three simple action problems, and 14 one-step addition and subtraction word problems. The students successfully completed the basic computation problems. However, according to the researchers no student achieved the 70% mastery level for the one step word problems, citing the use of the wrong operation as the reason for their failure to reach mastery. The researchers used twenty-one normally achieving third graders as their normative sample for this study.

The results of this study indicated that the utilization of the schema instruction strategy had a positive effect on the word problem solving skills of these four students. All of the students demonstrated significant improvement on their problem solving skills for one-step word problems. A review of the data showed that three of four of the students also had an increase in their performance on the two-step word problems. The students' performance also appeared to be affected when the researchers reduced the amount of individualized attention that they gave the students. For instance, one student demonstrated improvement over his baseline score on one-step word problems, but remained at baseline for the two and three-step word problems.

Improvement over baseline scores on one and two-step word problems were maintained on the follow-up tests that were administered.

Finally, in a study conducted by Fuchs and Fuchs (2002), the researchers attempted to describe the problem solving abilities of students with math disabilities with or without comorbid reading disabilities. They used three types of word problems for this study: arithmetic story problems, complex story problems, and real-world problem solving. These three types of word problems increased in difficulty level and progressed from the concrete that requires lower level thinking skills to the abstract requiring high order thinking skills.

The researchers identified sixty-two fourth grade students who would then be given assessments and grouped into samples for this study. All the students were individually administered an IQ test and achieved scores of 90 or higher. All the students also had IEP's that identified them as having a math disability. The researchers administered to all the students a Test of Computational Fluency developed by them in a previous study. This test gave the students three minutes to answer twenty-five basic math facts of addition and subtraction and was academically at the second grade level. Forty of the sixty-two students identified for the study scored below the national norm and were included in the sample that the researchers labeled as math disabilities. These forty students were then given the Comprehensive Reading Assessment Battery. The CRAB requires students to read aloud for three minutes, a passage containing 400 words and written at the third grade reading level. Of these forty students, twenty–two were identified as having a reading disability along with a math disability. The students who were identified with math disabilities and math and reading disabilities were included in the study.

The researchers found that as the difficulty level of the word problems increased, the scores of the students decreased. They also found that the scores on the arithmetic story problems were substantially higher than those on the complex story problems and the real-world story problems. The difference in scores between the complex story problems and real-world story problems was marginal. The students with only math disabilities scored higher on problem solving than students who exhibited both math and reading disabilities.

2.4.3 Synthesis

Although these studies attempted to obtain a definitive answer as to why students have difficulty with word problems, they were unsuccessful in demonstrating the relationship between the uses of cognitive strategies and comprehending the written text. Only in the study by Fuchs and Fuchs (2002) were the students in the samples tested for possible reading disabilities. The students were successful with the arithmetic word problems because the text was brief and simple. Their study demonstrated that as the word problems became more difficult with more extraneous wording the students were less successful. This seems to be indicative of a reading disability more than a math disability.

The success of the students who were given extensive practice in solving basic word problems in the study by Jitendra et al., (1998), could in part be explained by the direct instruction that the students received. The students were instructed on the use of a schematic map to help them translate the information from the word problem into categories or elements of the problem. The researchers used extensive modeling to demonstrate this strategy. The researchers also read the problems aloud to the students eliminating the possibility of the students not comprehending the written text. The results demonstrated that when the word problems were read to the students and a schematic map was utilized to categorize important information, the students were successful.

Students with learning disabilities are more successful when they are presented with explicit problem solving skills. This was verified in the study by Jitendra et al., (1999) where four special needs children were presented with one and two step word problems, a strategy diagram sheet and extensive practice. This study was limited however, because there were only four students and they were pulled from their regular classrooms for this instruction. Each student received individualized instruction from the researchers. Had the students remained in the regular classroom and the strategies been modeled, the results may have been different. Further research would have to be conducted to ascertain if when the students returned to the regular classroom they were able to use the strategies they were taught on their own.

Explicitly teaching for transfer has important educational implications. When educators teach children that learning is a continual process they help them to take ownership of their learning thereby progressing from one concept to the next. The study by Fuchs, et al.,

(2003) showed that when students receive explicit instruction on how to activate prior knowledge they then could begin to use that knowledge for solving more complex word problems. The students were able to discern the familiar from the unfamiliar problem structures and transfer their skills across these conditions. These studies demonstrated that with direct explicit instruction and modifications the students were able to be more successful in solving word problems.

2.5 COGNITIVE TUTORING SYSTEMS

The role of technology in teaching and learning, centers on the fact that the goals of the program are to support individual learning processes and deliver education to students in a different format. A cognitive tutoring program is a computerized program that is designed to emulate human tutors by providing students with individualized instruction (Wheeler & Regian, 1999).

In a study conducted by Wheeler and Regian (1999), the researchers were examining how the Word Problem Solving Tutor (WPS) improved the abstract reasoning of students on the word problem solving component. The participants of the study were 632 students from seven different high schools enrolled in elementary algebra. Tests were administered throughout the year to assess the students' abilities to solve algebra word problems. The study consisted of a control group, a placebo group, and treatment group with randomly assigned classes. The control group consisted of eight classes and the students in the control group received the traditional classroom instruction. The placebo group consisted of twelve classes and they received traditional classroom instruction plus one session per week with the placebo tutor. The treatment group consisted of thirty-two classes who received traditional classroom instruction plus one session per week with the WPS tutor.

The researchers found that the WPS tutor significantly improved the problem solving abilities of the students. However, they believe this positive result to be due in part to the fact that the students were provided with more individualized instruction. The placebo tutor did provide individualized instruction but did not provide specific problem solving steps for the students to use. This study demonstrated that when students were provided with strategies to solve word problems and more individualized instruction, that they can be successful. The researchers used a path analysis method to analyze their findings. The path analysis method examines the direct and indirect effects between the variables. The variables in this study that were examined were the effects that the pretreatment math skill had on both the concrete and abstract pretests and also the effect that the WPS tutor had on both the concrete and abstract posttest scores. The scores on the pre-treatment abstract and concrete pretests were .59 and .57 respectively. The scores on the abstract and concrete posttests were .86 and .69 respectively. These results indicated that the WPS tutoring system had more of an effect on the concrete skills of the students than on the abstract skills of the students. In the course of this study no assessments were given to assess reading ability. In fact, the readability level of the problems in the WPS tutor was never mentioned. The researchers made the assumption that any success was due to the WPS tutor system.

Meyer, Steuck, Miller, and Kretschmer, (2000), conducted a study involving the use of a cognitive tutoring system. The researchers attempted to answer the question about the effectiveness of tutors on instruction. The participants were 7^{th}, 9^{th}, and 10^{th} grade students at forty schools. The average amount of time spent in the computer lab for these students was 15-20 hours per school year. All students were pre-tested within the first six weeks to assess for the instructional effectiveness of both the regular classroom instruction and the computerized tutorial program. The control group received regular classroom instruction and the experimental group received instruction from the tutoring program approximately one day every two weeks. A posttest was given to ascertain if there was any instructional gain in either of the groups. The results showed that the control group had a 12% increase while the experimental group showed a 14% increase. The researchers believed that the gains could in part be due to the fact that academically better students learned more than their counterparts.

In reviewing the results for this study, a difference in gain of only 2% for the students who used the tutor seems low, although the fact that the students were only exposed to the non-traditional teaching by the tutoring program once every couple of weeks may account for some of the findings.

2.6 SUMMARY

The studies discussed in this review of the literature point to similar conclusions but they fail to recognize the implications that reading disabilities have on the word problem solving skills of students. The researchers viewed mathematical problem solving disabilities from a math perspective, however very little classroom attention was given to the language of mathematics. Teachers may teach the vocabulary that is connected to the required skill, but neglect to teach the use of this vocabulary in comprehending the written text. When a student fails to achieve the required mastery level on word problems the assumption is that they were not able to utilize the correct operation, when in fact they may have misinterpreted the language of the word problem. These students are then labeled as possessing a math disability and are referred for further math instruction. Many students who are receiving services for math disabilities are also receiving services for reading disabilities. Their math disabilities could be the result of a reading disability.

Further implications for study would indicate the need to view mathematical word problem solving disabilities from a reading perspective. The extraneous wording that is inclusive of many two and three step word problems can cause confusion for students who have limited abilities in reading. Removal of the extraneous and sometimes inferential wording without altering the answers to the word problems may afford the students the success they attempt to achieve.

The review of the literature demonstrated that listening comprehension is a pathway to understanding. However, the number of studies where the math text was read aloud to students as an accommodation is limited. Reading the text aloud to students did in fact demonstrate that students can attain higher success in solving math word problems when decoding barriers are reduced. It is important to note that the above results were limited to studies involving special education students. No studies were found that focused strictly on struggling readers and their ability to successfully solve math word problems when the text was read aloud to them. Furthermore, there were no studies that utilized both the reduction of the decoding barrier through reading aloud the text and explicit instruction of math word problems. This study attempted to demonstrate the effectiveness of using both.

3.0 METHODOLOGY

The purpose of this study was to investigate the use of a support system in which the math text was read to the students through the use of a text-to-speech engine (audio support system) embedded in a cognitive tutoring system. A multiple-case study design was used to obtain information regarding how and when students diagnosed with differential reading difficulties, used the audio support system and whether it had an effect on their math word problem solving abilities. Information on how successful these students were in learning from this cognitive tutoring system was acquired during this investigation. According to Yin (1994) a case study method is used when the need to identify contextual conditions is imperative to the study. This methodology allowed a more in-depth exploration relying on multiple sources of evidence and variables of interest beyond the use of specific data points.

Miles and Huberman (1994) describe how the use of a case study design increases the ability to generalize events that occur in a study to develop more compelling evidence with regard to the study outcomes. This facilitates a more in-depth understanding and explanation of the events that occurred and how study conditions may be related. This approach allows for the analysis of components of the study and their relationship to the study in its entirety without disregarding the whole, yet permits the researcher to visualize the whole in relation to its parts. Thus, this study was designed to investigate how struggling readers utilize an audio support system embedded in a cognitive tutoring system to enhance their word problem solving performance.

3.1 OVERVIEW OF STUDY

3.1.1 Design

This multiple-case study design was used to determine if the use of an audio support system embedded in a cognitive tutoring system facilitated the word problem solving skills of struggling readers. The case studies documented how students with different reading difficulties responded to the use of the audio support system and the other embedded devices in the cognitive learning system.

3.1.2 Research Questions

The following research questions guided this multiple case-study design:

1. In what ways did the use of an audio support system and other learning devices embedded in this cognitive tutoring system facilitate the word problem solving skills of struggling readers?

2. Were there differences in how these devices were utilized by the individuals who were identified as having existing decoding, fluency or comprehension difficulties?

3. What differences were there in the students' performance when the pre and post math word problem tests were read to them as compared to when the students read the test items themselves?

4. How successful were the students in learning from this cognitive tutoring system?

3.1.3 Overview of Procedures

The participants in this study were pre-assessed during two one-hour long sessions prior to beginning their tutorial sessions, using the Test of Mathematical Abilities, Second Edition (TOMA-2), MAZE-Curriculum Based Measurement (CBM), Dynamic Indicators of Basic Early Literacy skills-Oral Reading Fluency (DIBELs ORF), and the CORE Phonics Survey. The participants were also asked to complete a math attitude survey and a reading attitude survey.

The students were given the computation and story problems subtest of the TOMA-2 to assess their mathematical abilities. This standardized assessment contains only one version of the test and does not provide information regarding any accommodations for students. For comparison purposes the story problem subtest was administered twice to the students, once during the first session when the students read the story problems to themselves, and then again during the second session when the researcher read aloud the same problems to them. This was done to see if there were any differences in the number of problems solved correctly when the story problems were read independently and when they were read aloud to the students. The data obtained were then compared both individually and across students to see if any patterns existed in the problem solving skills of these struggling readers. The results of these assessments were then compared to the norm data used for standardization. This procedure enabled the researcher to identify those students who (a) were proficient at grade level computation skills and (b) were not proficient at solving word problems successfully at grade level when asked to read them independently, as generally required in math classrooms.

Students were then assessed for any specific deficiencies in decoding, fluency or comprehension using the CORE Phonics Survey which provided a decoding measure, the DIBELS ORF which provided a fluency measure, and MAZE CBM which provided a comprehension measure. This information was used to determine how the students in the study were similar and how they were different in terms of reading proficiency.

The students then completed eight intervention sessions using a math cognitive tutoring system. Anecdotal notes were taken by the researcher in five minute intervals at each of these sessions. These data were compiled and analyzed both individually and across students to determine similarities and differences among the participants' behaviors. At the conclusion of the eight intervention sessions the students were assessed using two posttests designed by the researcher. These posttests were similar to the questions presented to the students by the cognitive tutoring system during their intervention sessions. One posttest was read independently by the students and one was read aloud by the researcher. The results of the two posttests were compared, and similarities and differences among the participants were noted.

3.2 PARTICIPANTS AND SETTING

3.2.1 School District

The participants in this multiple-case study design were from a school district in southwestern Pennsylvania. The district consists of both rural and urban schools of which there are five elementary schools, two middle schools, and one high school. Total enrollment in the district was 3,747 students with a total percent of Free/Reduced enrollment in the district of 48.7%.

The district accountability reports for 2006-2007 indicated that Adequate Yearly Progress (AYP) was met in seven of the eight schools within the district. The one school that did not meet the state standards of AYP is currently in its second year of school improvement. The Pennsylvania System of School Assessment (PSSA) is given yearly to students in grades 3-8 and 11. The districts' overall results in Reading and Math on the PSSA indicated that of the 99% of the students who took the assessment, 58% were proficient or above in Reading and 64% were proficient or above in Math.

3.2.2 School

The students in this study were from a rural elementary school that houses grades K-6. Total enrollment in this school was 427 students with 53.3% of the students receiving Free/Reduced lunches.

The school accountability reports for 2006-2007 indicated that this school met AYP. The school's overall results in Reading and Math on the PSSA indicated that of the 100% of the students who took the assessment, 58% were proficient or above in Reading and 79% were proficient or above in Math.

3.2.3 Participants

The participants in this multiple-case study were three fifth grade students. All three students were Caucasian and were part of the free or reduced lunch program. There were two male students and one female student. For purposes of confidentiality the students are referred to as Adam, Ben, and Charlie and not by gender throughout this study. Initially, the subjects were identified in two ways: (1) Recommendation from the principal at the school, indicating that they have difficulties with reading, and (2) confirmation of that reading difficulty by reviewing their performance on the PSSA, a standardized test given by the school district (See Table 1 below for students' standardized test results information). Informed consent from the parents of each of the students was obtained (See Appendix A).

Table 1: Identification Criteria for Students: PSSA Test Results

Students	PSSA-Reading	PSSA-Math
Adam	Below Basic (1104)	Proficient (1434)
Ben	Basic (1238)	Proficient (1358)
Charlie	Below Basic (955)	Below Basic (1148)

The state cut scores for proficiency in Reading and Math were 1255 and 1246 respectively.

This study took place in the computer lab of the participants' school. Each participant was assigned an individual computer so that there was no outside influence that affected the resulting data collected. The researcher was granted access to the cognitive tutoring system via the internet. Each participant was assigned a student number by the researcher and was only permitted access to his/her own tutorial program. The individualized tutoring took place over a period of eight one-hour long intervention sessions. Each student was assessed prior to beginning their intervention sessions with the pre-assessments and was assessed with the posttests upon completion of their eight intervention sessions. (See Table 2 below for stages of the study).

Table 2: Stages of the Study Sessions

Instruments	1	2	3	4	5	6	7	8	9	10
TOMA-2 Student read	X									
TOMA-2 Read Aloud		X								
CORE Phonics Survey		X								
DIBELs ORF	X									
MAZE-CBM	X									
Interventions			X	X	X	X	X	X	X	X
Posttests A & B										X

3.3 THE PROGRAM OVERVIEW

All three students used a cognitive tutoring system designed to tutor students in math word problem solving skills. According to the developers, the cognitive tutoring program that was used in this study combines the proficiency of an online artificial intelligence system with the effectiveness of an individualized tutorial system (Apangea Learning, 2006). The system integrates intelligent software and live interactive support (via cyberspace) from certified teachers. It provides differentiated instruction for each student and makes one-on-one tutoring available anytime. It uses graphics, text, talking avatars, and an audio support system along with live interactive support from teachers. The readability level of the word problems in this tutorial system is at the fourth grade level. All the problems within this cognitive tutoring program align with the National Math Standards and Pennsylvania Math Standards.

Students are presented with a program tutorial before beginning their lessons to ensure that each of the students understands how to use the system. Through the use of the advanced pathways system, the teacher can set the number of modules and the number of levels (the progressions from simple to more difficult word problems) in each module that a student is required to complete. At the onset of each module, the students are presented with a tutorial that reviews the vocabulary and presents examples, through the use of graphics, for each level that was presented in the module. At the end of each module there is a quiz that the student completes before being permitted to move to the next module. The teacher can adjust the default setting for these quizzes that allows the student to advance after the required proficiency has been obtained. The system is designed so that each student can receive individualized instruction and can only advance to the next level after successfully completing the previous level. Students who have not successfully completed the word problems within the level are given the word problems they missed again before the system allows them to advance. If a student is having difficulty with a problem they have help available to them through the use of the talking avatar, the text-to-speech engine (audio support system), and the live interactive teachers. The text-to-speech engine was made available to provide literacy support for students. This audio support system allows the students to hear the problem being read aloud to them through the use of headphones. The talking avatar icon appears with a computerized hint (in a text box) to assist students who are having difficulty with a particular step of the problem solving process. The students have the option of clicking on the talking avatar to hear the computerized hint or reading the hint themselves.

The system has been designed so that teachers can generate reports from each student's session so that the student's progress can be monitored. These reports display information regarding the number of problems attempted, the number of problems completed correctly and incorrectly, and the number of times help was sought from the live interactive teachers. The system can also generate a step analysis report that gives the teacher information on which step of the seven-step scaffolded process the student had difficulty completing. A transcript of all interactions with the live interactive teachers can also be generated after each session.

3.3.1 Program Procedures and Implementation

This researcher was present for every session for each student and served in the capacity of a participant observer. The researcher took anecdotal notes throughout the sessions for use in the descriptive analysis of the intervention sessions. These notes included the number of times the students were off task, the number of times they used the text-to-speech engine for assistance, the number of times they asked the researcher for assistance, and the students' verbal and non-verbal responses during the sessions. The researcher also completed a post session interview with each student individually to ascertain if they used the avatar, the text-to-speech engine, the live tutors and why, and what went well and/or didn't go well for each student during each tutorial session.

The researcher set the requirements and restrictions within the study through the use of the special pathways element of the system. Students were given three modules to complete independently. The first module was addition and subtraction and had four levels with eight word problems per level. Module number two was multiplication and division and had five levels with eight word problems per level. The last module was decimals and had five levels with eight word problems per level. Descriptions of the modules, content by level, and sample problems are provided (See Appendices B, C, and D).

The program's skills-based seven-step problem solving approach is used for each of the word problems presented in each of the levels of each module. These problem solving steps are:

1. Explore the problem
2. Define the Goal
3. Identify the Variables
4. Build the Equation (word sentence)
5. Solve the Equation
6. Answer the Question
7. Explain Your Answer

The system directs the students through each of these steps and only upon completion of the previous step will the student be advanced to the next step. Each of these procedures is explained below through the use of the example problem in Figure 1.

Figure 1: Example Problem

Timothy has 2 hamsters and they recently had babies. The mother hamster had 6 babies. How many hamsters does Timothy now have?

The first step asks the student to Explore the Problem. In this step the problem is read aloud to the student through the use of the text-to-speech engine or the student can read the problem independently. In the second step, Define the Goal, the students are asked to use their mouse and drag the goal sentence to the box provided. (i.e., How many hamsters does Timothy have now?) They are then asked to restate the goal. (i.e., number of hamsters). In step number three the students are asked to Identify the Variables in the word problem. In this step they identify the key values by label and value. (i.e., label: hamsters, value: 2; label: babies, value: 6). Step number four asks the student to Build the Equation. The students are required to use their mouse and click on the labels using the correct mathematical procedure to form the word sentence. (i.e., hamsters + babies=number of hamsters). In step number five the students solve the equation by typing in the correct numbers from the word sentence using the correct mathematical process (i.e. 2+6=8). Step number six asks the student to Answer the Question by typing in the numerical answer to the problem and the units used. (i.e., number value: 8; units: hamsters). The last step requires the students to Explain Your Answer. Upon successful completion of each step the student progresses to the next question within the level.

A default mastery of 1.5 (the weighted range per question as set by the program in the specials pathways element of the system) was set for each level. The program is designed so that the students are required to complete all the word problems within each level. If a student fails to achieve the mastery required within the level, the students are given the problems that they missed first within the level to attempt again. If the student is not successful in completing the missed problems the system presents again all of the problems within the level.

Upon completion of each module a quiz was generated by the system. The quiz for addition and subtraction consisted of four word problems that each student was required to complete before advancing to the next module. The quiz for both the multiplication and division and the decimals modules consisted of five word problems. Students' success and progression to the next module was determined by a 60% attainment on the quiz. Students failing to attain the 60% on the quizzes were required to repeat the module; therefore, the students may not have completed all the modules and the varying paces of each of the students was observed.

3.4 MEASURES

All participants were pre-assessed for basic computational and math word problem solving skills. They were also pre-assessed for identification of pre-existing difficulties in fluency, decoding and comprehension. The instruments used for these assessments are listed and described below.

3.4.1 Math Instruments

The Test of Mathematical Abilities 2nd Edition, (TOMA-2) (Brown, Cronin, McEntire, 1994) was used to assess the participants' basic computational and word problem solving skills. The two subtests that were used in this study were the Computation subtest and the Story Problems subtest. The Computation subtest consists of thirty basic computation problems. The Story Problems subtest consists of twenty-five leveled word problems. This is a norm-referenced assessment, and was developed for use in grades 3 through 12. It has four subtests in the core battery that measure math performance on the two major skill areas of computation and story problems as well as vocabulary and general math applications. This test also includes a supplemental attitude survey. The standardization sample for this assessment consisted of 2,147 students from 26 states. Internal consistency reliability coefficients for the subtests were listed at above .80 and exceeded .90 for the quotient. Validity of test results for the TOMA-2 was based on Content validity, Criterion-Related Validity, and Construct Validity. Content validity was determined using an item analysis with scores ranging from .40-.70. Criterion-Related validity was determined in the first study by using the Key Math Diagnostic Arithmetic Test, the Peabody Individual Achievement Test and the Wide Range Achievement Test with scores ranging from .27-.56. The Criterion-Related validity score from the second study was determined using the SRA Achievement Series and the scores ranged from .34-.72. The Construct validity was determined using age differentiation and the scores ranged from .36-.61.

This assessment takes approximately 20-25 minutes to administer for the Computation and 20-30 minutes to administer for the Story Problems. This assessment can be administered to a group or individually.

3.4.2 Reading Instruments

To identify pre-existing difficulties with fluency, the Dynamic Indicators of Basic Early Literacy Skills TM 6th Edition (DIBELS) (Good, Kaminski, 2002b) fifth grade Benchmark 3, oral reading fluency subtest assessment was used. This subtest was administered to all three participants to determine their oral reading fluency rate. Each participant was given three on grade level passages to read and the median score was used to determine their fluency rate. DIBELS ORF is a standardized assessment that is individually administered. This subtest measures the fluency and accuracy with which a student reads text. Alternate Form reliability was used for the DORF and the scores ranged from .89-.96. Concurrent validity was determined using the Test of Oral Reading Fluency with scores ranging from .91-.96. This assessment is administered individually with each participant reading 3 one-minute passages.

The CORE Phonics Survey was administered to determine any pre-existing decoding difficulties of the participants. The CORE Phonics Survey is an informal assessment that assesses decoding skills through the use of pseudo words. The CORE Phonics Survey includes Alphabet Skills, Reading and Decoding Skills, and Spelling Skills. The Reading and Decoding portion (one subtest) of the CORE Phonics Survey was the only subtest used in this study since the participants are all fifth grade students and the researcher was only interested in identifying possible decoding difficulties in the participants. Pseudo words are an accepted form of assessment for identifying decoding deficiencies in students. The Reading and Decoding subtest consists of 10 short vowels in CVC words (5 real and 5 pseudo), 10 short vowels, digraphs and –tch trigraph words (5 real and 5 pseudo), 20 consonant blends with short vowels words (10 real and 10 pseudo), 10 long vowel spellings (5 real and 5 pseudo), 10 R-and I- controlled vowels (5 real and 5 pseudo), 10 variant vowels and diphthongs (5 real and 5 pseudo), and 24 multi-syllabic words (8 real and 16 pseudo). Since this is an informal inventory assessment there is no information regarding reliability or validity of this subtest however, it is similar to the Word Attack section of the Woodcock Reading Mastery. This assessment takes approximately 10-15 minutes and is administered individually.

The MAZE CBM was administered to determine any pre-existing comprehension difficulties of the participants. The MAZE CBM is an informal assessment that assesses the comprehension skills of students through the use of a Cloze technique. In this assessment students read a grade level passage in which after the first sentence, every seventh word has been replaced by three words in parentheses. Alternate Form reliability was used for the MAZE and the scores ranged from .82-.93. This assessment takes 3 minutes and is administered individually or in a group.

3.4.3 Posttests

At the conclusion of the eight intervention tutoring sessions the students were given two posttests to determine whether they could successfully complete the word problems presented to them without the use of the seven-step scaffolded problem solving process presented to them in this math tutorial system. Each posttest included 10 story problems, 4 from the addition/subtraction module, 5 from the multiplication/division module, and 1 from the decimals module (See Appendix E and F). This researcher read aloud the story problem questions from posttest A (which had 10 story problems) to each student, but the students were required to complete posttest B (which has 10 story problems) on their own without any assistance from the researcher. The researcher developed these posttests so that they were similar to the questions in the different levels of the modules that they completed in the cognitive tutoring system. These posttests were reviewed by math and reading experts. Data from both posttests were then analyzed to detect any differences in the posttest scores of the students when the story problems were read to them and when they were not.

3.5 DATA ANALYSIS

Comparative analysis of the data was done to determine how these students were both alike and different in their use of the cognitive tutoring system. This study consisted of both qualitative and quantitative data analysis. The qualitative data included the students' demographic and background information with regard to their standardized test scores, their responses to their two posttests and the researcher's narration from the field observation notes.

The quantitative data included information from both the session observations and the print out reports obtained after each tutorial session. The session observations included the use of time sampling of behaviors not available on the printout reports. These data included the number of times the students asked the researcher for assistance, their verbal and nonverbal responses to tasks (facial expressions, sighs, etc.), and the number of times they were observed using the text to speech engine in each tutoring session.

This multiple-case study design used a conclusion drawing and verification analyses for data interpretation (Miles & Huberman, 1994). Conclusion drawing and verification require the researcher to interpret the data using a compare and contrast format noting specific patterns and themes, and finally a triangulation of the data sources. A synthesized approach was used to view each case independently and as part of the whole. This allowed the researcher to examine each student as a separate case and through the compare and contrast format to synthesize the information to develop conclusions based on their commonalities or differences.

3.5.1 Overview of Pre-Assessments

The types of scores used for data analysis in both TOMA-2 subtests were: raw scores, percentile rank, standard scores, and descriptive ratings. The raw scores indicate the number of items correct in each subtest. The percentile rank is representative of a value on a scale of 100 that indicates the distribution that is equal to or below that particular value. The standard score is derived from a scale that ranges from 1 to 20 with the mean of 10 and a standard deviation of 3. The descriptive rating is based on the Standard score.

Pre-assessments were given to reveal any pre-existing reading difficulties in the areas of decoding (CORE Phonics Survey), fluency (DIBELs ORF), and comprehension (MAZE-CBM). A score of 3 or more missed on a 10 item subtest of the decoding assessment indicates that a student would benefit from more direct instruction in that particular area. Scoring on the multisyllabic words portion of the decoding subtest is given in the form of number correct out of number possible, with percentages listed in parentheses. Three, on-grade level passages, (DIBELs ORF) were administered with the median score being used to determine fluency rate. Scores for the fluency assessment indicate that a student reading at or above 104 wpm is considered “low risk”, 81-103 wpm indicates “some risk”, and 80 wpm or below indicates that a student is “at risk” for reading failure. A fall benchmarking score of 16 or above on the fifth grade level MAZE-CBM indicates that a student is on target.

3.5.2 Overview of the Tutorial Sessions

Each participant used a cognitive tutoring system designed to tutor the students in math word problem solving skills. The program uses graphics, text, talking avatars, and an audio support system along with the live interactive support from teachers, and a skills-based seven-step problem solving approach to solve word problems. These problem solving steps are:

1. Explore the problem
2. Define the Goal
3. Identify the Variables
4. Build the Equation
5. Solve the Equation
6. Answer the Question
7. Explain Your Answer

Data in the form of printout reports were obtained after each tutorial session. These reports contained the following information; the number of problems attempted (with correct/incorrect), the number of avatar helps, the number of avatar helps for each step of the problem solving process, and the end of the module quiz results.

The students were required to complete the introduction to the tutoring program prior to beginning work in the assigned modules. This introduction demonstrated how to use the system. Then the students were assigned three grade level modules to complete independently during the eight tutorial sessions. These modules were addition/subtraction, multiplication/division, and decimals. There were four levels in the addition/subtraction module and five levels in both the multiplication/division and decimals modules. Each of these levels contained eight word problems. The first printout report obtained showed the number of problems each student attempted during each session. This report also shows the number of problems the student correctly answered and the number of problems that were answered incorrectly. The module(s) that the students were in during each session is also listed.

The second print-out report obtained showed the number of avatar helps during a session. The talking avatar is an animated human form used in this computer program to assist students when they are having difficulty with a particular step of the word problem. This avatar automatically pops up on the computer screen to tell the students which part of the problem is incorrect. If the students are wearing their headphones they will hear the avatar reading the text from the box on the screen. Each time an avatar pops up on the screen it is recorded in the program and a printout report can be generated to show these results. This information is useful to a teacher for two reasons. First, it can assist the teacher in discerning with which step of the problem solving process the student is having difficulty. Second, the teacher can use the information in conjunction with the number of problems completed printout to determine if the student is having difficulty with word problems at a particular level.

Although this program uses a seven-step problem solving process to solve word problems, the reports provide information only on steps 2 through 6. Through the use of a text-to-speech engine the problems are read to the students in Step 1, therefore there are no data to report. Step 7 of the process requires the students to explain their answer. This information is not made available on a report.

3.5.3 Overview of Analysis of Anecdotal Notes

The participants attended eight one-hour long tutoring sessions over a period of three months. During these sessions the researcher took anecdotal notes every 5 minutes for a total of 96 intervals. These observational notes included the number of times that the participants were off task, the number of times they used the text-to-speech engine for assistance and the number of times they asked the researcher for assistance during the sessions. Because the researcher was acting as participant observer only throughout the sessions, the students were directed to go back to the computer screen and use the embedded tools provided by the computer program for help when they asked the researcher for assistance. The data from these anecdotal notes were totaled over all eight sessions.

At the end of each tutorial session each participant was asked the following questions:

1. Did you use the talking avatar today? Why?
2. Did you use the text-to-speech engine today? Why?

3. Did you use the live tutors today? Why?
4. What went well for you today?
5. What didn't go well for you today?

Because there was a computer malfunction during the fifth session, the talking avatar, the text-to-speech engine, and the live tutors were not available.

3.5.4 Overview of Posttests

The students were given two posttests developed by the researcher. These posttests were developed so that they were similar to the questions in the different levels of the modules that the students completed in the cognitive tutoring system. Posttest A was read aloud to the students by the researcher and Posttest B was taken independently by the students. Each posttest contained 10 word problems; one from each of the four levels within the Addition/Subtraction module, one from each of the five levels within the Multiplication/Division module, and one from the first level of the Decimals module. The researcher chose to include only one question from the Decimals module because none of the participants completed all three modules.

3.6 SUMMARY

A multiple-case study design was used to describe the effects of a cognitive tutoring system on the math problem solving skills of struggling readers. The participants in this study were three fifth grade students who were recommended for participation by the principal of their school. The participants attended eight tutoring sessions. The data collected from each session included the researcher's observational data and the printout reports. Interviews of the participants were completed after each session to obtain information regarding the use of the talking avatar, the text-to-speech engine, and the live tutors. Information was also obtained regarding the participants' interpretation of each session. Data analysis through conclusion drawing was used to provide a detailed description of the effects that the cognitive tutoring system had on the word problem solving skills of these struggling readers.

4.0 RESULTS

Research has demonstrated that when math word problems are read aloud to students with reading difficulties, they are more successful in solving the word problems presented to them. The purpose of this study was to investigate the extent to which the use of a text-to-speech engine embedded in a computer based cognitive tutoring system facilitated the word problem solving performance of struggling readers. Participants in this study exhibited varying levels of reading deficiencies. The number of times each participant used the avatar for help in each step of the seven-step problem solving process was of particular interest.

4.1 OVERVIEW OF DATA ANALYSIS

Both quantitative and qualitative data were collected to address the research questions. The quantitative data included standardized reading test scores administered by the district, information from the printout reports obtained after each tutorial session, pre and posttest scores on various assessment tasks, observational field notes from the researcher of how often the participants were observed using the text-to-speech engine for additional assistance in reading the word problems and how often they asked the researcher for assistance with the word problems. The qualitative analysis included the students' demographic and background information obtained through informal interviews with the students and their teachers, and the researcher's narration from the field observation notes.

This multiple-case study investigated whether the use of an audio support system had any effect on the word problem solving performance of struggling readers when they were presented with a seven-step scaffolded process to solve word problems. It also attempted to explain whether the use of the audio support system was essential to the achievement of the students who were identified with different reading difficulties, specifically decoding, fluency, and comprehension difficulties. Of equal importance during this investigation was whether there were differences in how the embedded devices were utilized by the individual participants and how successful each student was at learning from this cognitive tutoring system. The analyses of the data obtained from the pre-assessments, the tutorial sessions, and the posttests focuses first on the individual participants and then comparatively across all three.

The framework for analysis of each individual student is as follows. Each student is identified by a pseudonym (Student Adam, Ben, Charlie) so that neither their gender nor any other identifying information is disclosed. This study included two males and one female however all the participants are referred to in the analysis of their results using only pronoun references to the male gender. The flow of data results for each child is as follows: pre-assessments, tutorial sessions, analysis of anecdotal notes, posttests, and finally a summary statement. The following table indicates how each question was analyzed in this study.

Table 3: Question Analysis

Question #	Pretest/ Posttests Scores	Researcher Observations	Reports	Student Interviews
1) In what ways did the use of an audio support system and other learning devices embedded in this cognitive tutoring system facilitate the word problem solving skills of struggling readers?		X	X	X
2) Were there differences in how these devices were utilized by the individuals who were identified as having existing decoding, fluency, or comprehension difficulties?		X	X	X
3) What differences were there in the students' performance when the pre and post math word problem tests were read to them as compared to when the students read the test items to themselves?	X			
4) How successful were the students in learning from this cognitive tutoring system?	X	X	X	

4.2 ADAM

Adam is a 10 year old fifth grader who was diagnosed with severe ADHD in the second grade; he takes daily medication for this neurobehavioral developmental disorder. According to his teachers, Adam has a propensity for getting into trouble in school and he missed one of the tutorial sessions due to suspension from school for fighting. However, Adam appeared eager to be part of this research study and actively participated at the sessions that he attended.

The results of the TOMA-2 computation subtest indicate that Adam scored in the average range and did not have any computation difficulties. Although he had a descriptive rating of 'average' on both story problems read independently and aloud by the researcher, there was an increase in performance when the story problems were read aloud to Adam. However, even though his percentile increased from the 37th to the 63rd percentile, he was only able to get 2 more of the 25 problems correct when the story problems were read aloud to him.

Table 4: TOMA-2 Results-Adam

Subtest	Raw Score	Percentile Rank	Standard Score	Descriptive Rating
Computation	14/30	50th	10	Average
Story Problems Read Independently	7/25	37th	9	Average
Story Problems Read Aloud by Researcher	9/25	63rd	11	Average

Pre-assessments were given to identify any pre-existing reading difficulties in the areas of comprehension, fluency, and decoding. Adam's subtest results for the reading pre-assessments are listed in Table 5.

Table 5: TOMA-2 Results-Adam

Assessment	Score	Descriptive Rating
MAZE- CBM	13	Below Target
DIBELs ORF	104	Low Risk
CORE Phonics Survey		
Short vowels CVC words	9/10 (90%)	Low Risk
Short vowels, digraphs, and –tch trigraph	8/10 (80%)	Low Risk
Consonant blends with short vowels	19/20 (95%)	Low Risk
Long vowel spellings	9/10 (90%)	Low Risk
Variant vowels and diphthongs	10/10 (100%)	Low Risk
R- and I- controlled vowels	9/10 (90%)	Low Risk
Multisyllabic words	13/24 (54%)	More direct instruction needed

The reading results indicated a difficulty with reading comprehension as measured by the MAZE-CBM and a need for more direct instruction in the area of multisyllabic words as measured by the CORE Phonics Survey. He scored at low-risk for both short and long vowels indicating that he has an understanding of vowel patterns. He also scored at low-risk on the DIBELs ORF indicating that he is a fluent reader.

4.2.1 Adam's Tutorial Sessions

Adam attended seven of the eight tutorial sessions, missing session #2 due to a suspension from school. In Table 6, the number of problems attempted during each session, the number of problems correctly answered, and the number of problems answered incorrectly are identified. The module that he was in during each session is also listed.

Table 6: Class Problems Completed-Adam

Session #	# of problems attempted	# of problems correct	# of problems incorrect	Module
1	Introduction			
2	Student was absent			
3	3	3	0	Add/Sub
4	6	6	0	Add/Sub
5	7	7	0	Add/Sub
6	5	4	1	Add/Sub
7	7	7	0	Add/Sub
8	4	4	0	Add/Sub

Adam was successful in completing only the Addition/Subtraction module during the eight tutoring sessions. He took the entire first session and the beginning of the third session to complete the introduction; only leaving 5½ sessions for the actual intervention on the cognitive tutoring system. Because of a computer malfunction, the text-to-speech engine and the talking avatar were unavailable during session #5. This malfunction appeared to have no adverse effect on Adam during session #5; Adam attempted and solved seven problems, a number similar to what he did in other sessions. Although Adam was able to correctly answer 97% of the problems attempted during the 5½ sessions, this was not unexpected since students are given support until they respond correctly. However, though correct, Adam was somewhat slow in completing the problems. According to information received from the technical department of Apangea Learning Inc., students generally complete a level in one 45 minute session. Adam took 5½ sessions to complete the four levels within the Addition/Subtraction module of the tutoring program.

The number of avatar helps and the number of avatar helps per problem completed during each session are identified in Table 7.

Table 7: Total Avatar Helps per Session (Addition/Subtraction only)-Adam

Session #	# of Problems Completed	# of Avatar Helps	# of Avatar Helps per Problem Completed
1	Introduction	Introduction	Introduction
2	Student absent	Student absent	Student absent
3	3	8	2.7
4	6	25	4.2
5	7	9	1.3
6	5	20	4.0
7	7	12	1.7
8	4	8	2.0
Total	**32**	**82**	**2.6**

The data indicate that Adam used the avatar more during sessions 4 and 6. This information is important but can not be used by itself to determine areas of difficulty that this student encountered. Although there are no conclusive data to indicate why Adam had more difficulty in sessions 4 and 6, it can be noted by the number of problems completed in each session that the level of difficulty of the problems increased in both of those sessions. A more thorough description of the areas of difficulty in the seven-step problem solving process encountered by this student is listed in Table 8.

Table 8: Avatar Helps per Problem-Solving Step Results (Add/Sub only)-Adam

Session #	# of Problems Completed	Step 2 Define the Goal	Step 3 Identify the Variables	Step 4 Build the Equation	Step 5 Solve the Equation	Step 6 Answer the Question	Total Avatar Helps per Session	# of Avatar Helps per Problem Completed
1	Intro	Intro	Intro	Intro	Intro	Intro	Intro	Intro
2	Student Absent	Student Absent	Student Absent	Student Absent	Student Absent	Student Absent	Student Absent	Student Absent
3	3	0	3 (38%)	1 (13%)	0	4 (50%)	8	2.7
4	6	2 (8%)	1 (4%)	1 (4%)	0	21 (84%)	25	4.2
5 *	7	0	7 (78%)	0	0	2 (22%)	9	1.3
6	5	0	4 (20%)	9 (45%)	0	7 (35%)	20	4.0
7	7	1 (8%)	6 (50%)	5 (42%)	0	0	12	1.7
8	4	0	6 (75%)	2 (25%)	0	0	8	2.0
Total	**32**	**3 (4%)**	**27 (33%)**	**18 (22%)**	**0**	**34 (41%)**	**82**	**2.6**

***** indicates no text-to-speech engine or talking avatar during this session

Although this program uses a seven-step problem solving process to solve word problems the printout reports provide information about steps 2 through 6. The data results from Table 8 indicate that overall Adam experienced the most difficulty with step 3 (Identify the Variables) during sessions 5 and 8. Although the percentage of avatar helps during sessions 5 and 8 are close (78% and 75% respectively) the variation occurs because of the number of problems completed during these two sessions. During session #4, Adam demonstrated more difficulty with step 6 (Answer the Question) than in any other session. The difficulty for Adam occurred when he was asked to identify the "units" in the problem. A specific example of this demonstrated difficulty can be seen in the following problem taken from Adam's tutorial session #4.

Question: Noelle and Damian want to buy a pizza at Patty's Pizza Place. They have $14 and the pizza costs $9. How much extra money do they have?

Each time he incorrectly identified the "units" in the sample problem above an avatar would appear on the screen with a computerized hint in a text box to guide him to the correct answer. The "units" identified in this problem refers to "dollars". Adam typed in the word "money", and the avatar appeared to let him know that "money" was incorrect by providing a hint in the textbox stating that the "units" was incorrect. During this session he encountered problems with identifying the units in 5 of the 6 problems he completed.

The largest proportion of Adam's avatar usage was for step 6 (Answer the Question), then step 3 (Identify the Variables), then step 4 (Build the Equation). The avatar uses for step 6 always pertained to identifying the "units" in the problem. The data from Table 7 also indicate that there did not appear to be a systematic decline in the number of avatar helps across sessions as Adam progressed throughout the module.

As mentioned previously, Adam completed only the Addition/Subtraction module of the program. The class quiz taken at the end of a module looks only at the computation skills required to work in that module; Adam scored 100% on both the pre-quiz and the post-quiz. Adam was observed using the interactive support from the live tutors on two separate word problems during session #6.

The posttests were administered after the last tutoring session. Adam scored 60% correct on the 10 posttest questions read independently and 70% correct on the 10 posttest questions read aloud by the researcher. These data indicated little difference in performance between the test read to him and the one he read independently and most likely the difference was due to chance. Because Adam was only able to complete the Addition/Subtraction module during the tutorial sessions attended, an analysis of the questions about Addition and Subtraction was conducted. The results of Adam's pretests (TOMA-2) were compared to his posttests. Results from both the pre-tests (TOMA-2) and the posttests are listed in Table 9.

Table 9: Analysis of Addition/Subtraction Problems-Adam

TOMA-2 Read independently by the student (n = 13)	**TOMA-2 Read aloud by the researcher (n=13)**	**Posttest B Read independently by the student (n=4)**	**Posttest A Read aloud by the researcher (n=4)**
7 (54%)	9 (69%)	3 (75%)	4 (100%)

Results from the pre-tests read both independently by the student and read aloud by the researcher were compared to the posttests read both independently by the student and read aloud by the researcher. Although there was a slight improvement on the TOMA between tests read independently and those read aloud by the researcher, again there was little difference on the posttests.

4.2.2 Qualitative Results

Analysis of the anecdotal notes taken on Adam during the sessions he attended is based on 84 intervals of observational data. Adam was observed being on task only 68% of the time. He was observed playing with the headphones, moving the rolling chair from front to back and side to side, focusing on what the other students were doing and commenting on it, getting the headphone wire caught under the chair wheels, and asking to be excused to the restroom.

Adam was observed using the text-to-speech engine for extra help during only 4% of intervals. The text-to-speech engine was unavailable to the students during session #5 due to a computer malfunction. It was during this session that he was most off task. The lack of the text-to-speech engine did not contribute to Adam being off task. It was observed that Adam quite often either removed his headphones during his tutorial sessions or didn't put them on at all. He requested assistance from the researcher during 25% of the intervals over seven sessions. Adam asked for assistance the most when the level of difficulty of the problems increased. Adam exhibited a very positive attitude about the work and using the tutorial program. Often, when engaging in informal conversations with the researcher about the program, he would become very chatty and silly, yet appeared excited about the sessions.

Adam was also observed attempting to bypass the seven-step problem solving process by clicking on a bypass icon that would allow him to answer the question without the use of the seven-step process. The computer bypass icon gives the students approximately 45 seconds to answer the problem successfully before being directed back to the first step of the seven step process. Although Adam attempted to use this bypass icon several times during different sessions, he was never successful in answering the problem within the allotted time and therefore was directed back to the first step of the process.

During the tutorial sessions he would become agitated rather easily. The verbal signs of frustration came in the form of outbursts such as "I hate addition and subtraction". Adam appeared to be unaware of the effects the outbursts had on the other participants. His unhappiness at having to begin with an introduction to the program was evident when he began mumbling about the program, and further when he requested a piece of paper to use in completing the quiz to the addition and subtraction module. The introduction to the program takes the students step by step through the problem solving process. Adam asked for assistance with the first problem in the addition/subtraction module probably because he had paid very little attention during the introduction. During the introduction Adam was observed playing with his headphones and rocking his chair back and forth repeatedly.

Verbal displays of frustration appeared more often when he was working on step 6 of the problem solving process. This step asks the students to answer the question by requiring that they write the type of "units" used in the problem. He had difficulty in discerning what the units were in the problems and oftentimes had to ask the researcher for assistance. This was only done after several unsuccessful attempts to complete this portion of the problem and he became verbally agitated when the system would not accept his answer. On one occasion, Adam became verbally upset when as a result of not completing a problem in the previous session he was given the same problem again by the tutorial program. He stated, "I already did this one….this is bull!" Another display of verbal frustration was evident when he stated, "There is something wrong with this computer". This came about when he was using names instead of amounts in step 4, Building the Equation. Adam blamed his mistakes on the computer program instead of taking responsibility for his incorrect answers.

Along with the verbal displays of frustration there were verbal displays of affirmation, although they appeared less often. When taking the pre-quiz for the addition/subtraction module Adam stated, "I just figured that out in my head. I've never done that before!" Other demonstrations of excitement at having achieved were, "Yes! I got it right on the first time", "It gave me the answer. Cool!", "This is so easy!"

The non-verbal displays of frustration exhibited by Adam were just as distracting to the other participants as the verbal displays of frustration. For example, Adam would constantly rock back and forth in the wheeled chair. During one session, Adam wore a plastic-type jogging suit to school and was wiggling around in the chair. At one point he began physically smacking his head with his hand. During every session he constantly threw his hands up in the air, sighed, and repeatedly took his headphones off and then put them back on again. Adam did not display any non-verbal forms of affirmation during the sessions.

Due to a computer malfunction during the fifth session the talking avatar, the text-to-speech engine, and the live tutors were unavailable. Therefore, data on the uses of these embedded devices for this student were obtained for 6 sessions only since Adam was absent for one of the eight sessions. In the interviews across the sessions Adam responded “yes” to having used the talking avatar (to have the text in the text box read aloud) for 5 out of 6 sessions. At the beginning of the sessions, he said his use of the talking avatar was attributed to “needing a little bit of help”, but by the end of the total number of sessions the use was just because the icon would “pop up” and let the him know what was wrong with the answer to the problem. The text-to-speech engine was only used once throughout the sessions and that was during the first class. Adam explained that the only reason he used it was because he did not want to read the problem. Adam was observed using the live tutor device twice during session #6. When asked why, he replied that this device was used because of difficulty with a more complex problem. Adam’s responses for the question regarding what went well for the session were; “I had fun”, and “I got more points”. He responded to the question about what didn’t go well today with “nothing” for each of the sessions except the seventh session when he needed to use the live tutor and felt frustrated because “I’m usually good in math”. Adam felt that using the live tutor and asking for help meant an incapability to be successful with the program.

4.2.3 Summary for Adam

Adam presented the most challenges for the researcher. It was difficult to discern whether his responses were due to the medication for ADHD wearing off by the end of the school day or if they were true responses to frustration. He also was the most verbal of the participants. There appeared to be a certain level of comfort on his part with the researcher as indicated by his willingness to verbalize as much as he did. He did appear to be confident in math, but became easily frustrated when the computer malfunctioned.

Adam often took off the head phone set and therefore was reading the problems independently. He was observed typing in answers to the problems without really reading and understanding what was being asked. Because the avatar icon would appear and provide a computerized hint in the textbox to let him know what was incorrect in the answer he did not seem to feel responsible for avoiding mistakes; when prompted he would just type in something new whether it made sense or not. In other words the avatar icon became a “crutch” for Adam. It was difficult to know whether Adam used the avatar more for a specific problem because these data were not available on the printout reports. Analysis of whether he was able to apply the seven-step problem solving process to independent work outside of the computer program could not be determined by the posttests because he did not show all his work in the spaces provided for answers on the posttests. His utilization of the live interactive tutors on one occasion was not because he needed to use this device, but because he wanted to interact with someone on the computer.

4.3 BEN

Ben is a 10 year old fifth grader who, according to his teachers, actively participates in class. He has a tendency to be domineering and tattles on his fellow students’ behaviors if they seem inappropriate to him. His pre-assessment subtest results for the TOMA-2 are listed in Table 10.

Table 10: TOMA-2 Results-Ben

Subtest	Raw Score	Percentile Rank	Standard Score	Descriptive Rating
Computation	14/30	50th	10	Average
Story Problems Read Independently	10/25	75th	12	Average
Story Problems Read Aloud by Researcher	11/25	84th	13	Above Average

The results of the computation subtest indicate that he did not have any computation difficulties; he scored at the 50th percentile. Ben’s results from his story problem subtest indicate that he did not have any difficulties with the story problems presented to him. Ben was able to successfully complete one more story problem when the problems were read aloud by the researcher compared to when read independently.

The reading pre-assessments results for Ben are listed in Table 11.

Table 11: MAZE-CBM, DIBELs ORF, and CORE Phonics Survey Results-Ben

Assessment	Score	Descriptive Rating
MAZE- CBM	16	On Target
DIBELs ORF	97	At Some Risk
CORE Phonics Survey		
Short vowels CVC words	7/10 (70%)	More direct instruction needed
Short vowels, digraphs, and –tch trigraph	7/10 (70%)	More direct instruction needed
Consonant blends with short vowels	13/20 (65%)	More direct instruction needed
Long vowel spellings	6/10 (60%)	More direct instruction needed
Variant vowels and diphthongs	7/10 (70%)	More direct instruction needed
R- and I- controlled vowels	8/10 (80%)	Low Risk
Multisyllabic words	16/24 (67%)	More direct instruction needed

The reading results for Ben indicate difficulty with fluency and decoding skills as measured by the DIBEL's ORF and the CORE Phonics Survey. The MAZE-CBM results indicate that Ben does not have difficulty with comprehension of what he reads. The principal of Ben's school recommended him for this study because he scored less than proficient in Reading on the PSSA.

4.3.1 Ben's Tutorial Sessions

Ben attended all eight tutorial sessions. Table 12 shows the results for the number of problems attempted, the number of problems correctly answered, and the number of problems answered incorrectly in each session. The modules that he was in during each session are also listed.

Table 12: Class Problems Completed-Ben

Session #	# of problems attempted	# of problems correct	# of problems incorrect	Module
1	Introduction			
2	1	1	0	Add/Sub
3	10	10	0	Add/Sub
4	14	14	0	Add/Sub
5	6	6	0	Add/Sub
6	13*	13	0	Multi/Div
7	20	20	0	Multi/Div
8	5	5	0	Multi/Div

* One problem was Addition/Subtraction

Ben was successful in completing the Addition/Subtraction module and 37 of 40 of the questions in the Multiplication/Division module. He took the entire first session and most of the second session to complete the introduction. He had to repeat the introduction because he failed to answer the post-introduction questions correctly. The tutorial system automatically repeats the introduction if students fail to successfully complete the post-questions after the introduction. Ben relied heavily on the use of the text-to-speech engine to read the problems to him and during session 5 when the text-to-speech engine was unavailable due to a computer malfunction, Ben was only able to successfully complete six word problems. During session 5, Ben demonstrated signs of frustration such as sighing aloud and rubbing his head with his hand. There is a noticeable difference in the number of problems completed during session 8 as well; Ben was only able to successfully complete five word problems in session 8. Ben had come to this tutorial session visibly frustrated and verbalized that it had been a bad day. Although the data indicate that Ben completed fewer word problems in sessions 5 and 8, he was able to answer all the word problems correctly in each of the sessions.

The second printout report showed the number of avatar helps during each session. Ben's results are listed in Table 13.

Table 13: Total Avatar Helps per Session-Ben

Session #	# of Problems Completed	# of Avatar Helps	# of Avatar Helps per Problem Completed
1	Introduction	Introduction	Introduction
2	1	11	11.0
3	10	48	4.8
4	14	36	2.6
5	6	13	2.2
6	13	21	1.6
7	20	41	2.0
8	5	16	3.2
Total	**69**	**186**	**2.7**

The data indicate that Ben used the avatar more during sessions 3 and 7. However, when compared to the number of avatar helps per problem completed, Ben appeared to have the most difficulty in session #2, and some difficulty in session #3. This information is important but can not be used by itself to determine areas of difficulty that this student encountered. A more thorough description of the areas of difficulty in the seven-step problem solving process encountered by this student is listed in Table 14.

Table 14: Avatar Helps per Problem-Solving Step Results-Ben

Session #	# of Problems Completed	Step 2 Define the Goal	Step 3 Identify the Variables	Step 4 Build the Equation	Step 5 Solve the Equation	Step 6 Answer the Question	Total Avatar Helps per Session	# of Avatar Helps per Problem Completed
1	Intro	Intro	Intro	Intro	Intro	Intro	Intro	Intro
2	1	0	9 (82%)	2 (18%)	0	0	11	11.0
3	10	0	6 (13%)	2 (4%)	0	40 (83%)	48	4.8
4	14	0	10 (28%)	7 (19%)	4 (11%)	15 (42%)	36	2.6
5*	6	0	5 (38%)	6 (46%)	1(8%)	1 (8%)	13	2.2
6	13	0	4 (19%)	6 (29%)	1 (5%)	10 (48%)	21	1.6
7	20	1 (2%)	7 (17%)	9 (22%)	0	24 (59%)	41	2.0
8	5	1 (6%)	6 (38%)	3 (19%)	2 (13%)	4 (25%)	16	3.2
Total	**69**	**2 (1%)**	**47 (25%)**	**35 (19%)**	**8 (4%)**	**94 (51%)**	**186**	**2.7**

* indicates no text-to-speech engine or talking avatar during this session.

The results from Table 14 indicate that Ben had the most difficulty with steps 6, 3, and 4. In session #3, 83% of his total avatar were used to complete step 6 (Answer the Question) of the problem solving process. The data from session #2 demonstrates that Ben needed assistance with identifying the variables 9 times, and this by itself is not significant. However, Ben only completed one problem during this session, and needed 9 assists (82% of his total avatar usage) to correctly identify the variables. Ben was observed entering names of the months for the variables in the question completed during that second session. A specific example of this demonstrated difficulty can be seen with the following problem taken from Ben's tutorial session #2.

Question: There are not many sunny days in Shady Town. In July, there were only 9 sunny days. In August, there were only 12 sunny days. How many total sunny days were there in Shady Town in July and August?

Ben entered the names of the months for the variables, as well as the words "sunny days". After several attempts to answer this portion of the question using those same words, Ben finally entered the numbers for the variables. As Ben became more accustomed to the cognitive tutoring program he was able to identify the variables more readily in the problems he completed. However, the data do indicate that about 25% of avatar helps related to conceptualization of the word "variables" throughout all the sessions.

The data also indicate that Ben demonstrated some difficulty with Step 4 (Building the Equation). However, Ben's usage of the avatar for this step of the problem solving process does not appear significant. Only 19% of the avatar uses were for help with Step #4. The data from Table 13 indicate that Ben used the assistance of the avatar for Step 6 (Answer the Question) more often than for any of the other steps of the process, accounting for 51% of his total avatar uses. The data also indicate that he used the avatar for this step the most during session 3, where he answered 10 Addition/Subtraction questions, but used the avatar for assistance 40 times. Ben was observed consistently entering the wrong "units" for each of the 10 questions he answered. It was apparent that he had difficulty in conceptualizing what a "unit" was. This is an illustration of a math vocabulary problem. Although the data indicate that Ben experienced some difficulty with Step 6 of the problem solving process, his rate of progress during the tutorial sessions exceeded both Adam and Charlie's.

Ben completed both the Addition/Subtraction module and the Multiplication/Division module of the program. The class quiz results for the Addition/Subtraction module indicate that Ben scored a 2 of 4 (50%) on the pre-quiz and increased to 3 of 4 (75%) on the post-quiz for the same module. The class quiz results indicate that he completed the Multiplication/Division module during session 8. He scored a 3 of 5 (60%) on the pre-quiz but only 1 of 5 (20%) on the post-quiz for this module. This substantial decrease of 40% from the pre-quiz to the post-quiz may have been due to Ben's apparent fatigue, as described in the anecdotal notes for his last session.

Ben scored 60% correct on the 10 posttest problems read independently and 50% correct on the 10 posttest questions read aloud by the researcher. These data indicate that he was somewhat less successful when the word problems were read aloud by the researcher. He completed both the Addition/Subtraction and Multiplication/Division modules during the tutorial sessions. Questions numbered 1-4 were consistent with the types of questions in the Addition/Subtraction module, questions 5-9 were consistent with the types of questions in the Multiplication/Division module and question 10 was consistent with the types of questions in the Decimals module. A comparison of the data between the two posttests focusing on the questions consistent with the Addition/Subtraction module demonstrates that he was more successful when the problems were read independently, answering 4 of 4 (100%) correctly compared to the 3 of 4 (75%) correctly answered in the posttest read aloud by the researcher. A comparison of the data between the two posttests focusing on the questions consistent with the Multiplication/Division module demonstrates that he scored the same on these problems, answering only 1 of 5 (20%) of the problems correctly. Because Ben was the only student to complete more than one module during the intervention sessions, an analysis of only the questions about Addition/Subtraction will be used for comparison purposes. The results of Ben's pre-tests (TOMA-2) were compared to his posttests. Results from both the pre-tests (TOMA-2) and the posttests are listed in Table 15.

Table 15: Analysis of Addition/Subtraction Problems-Ben

TOMA-2 Read independently by the student (n = 13)	TOMA-2 Read aloud by the researcher (n=13)	Posttest B Read independently by the student (n=4)	Posttest A Read aloud by the researcher (n=4)
9 (69%)	10 (77%)	4 (100%)	3 (75%)

Results from the pre-tests read both independently by the student and read aloud by the researcher were compared to the posttests read both independently by the student and read aloud by the researcher. The data indicate that Ben answered one more problem correctly when the word problems were read aloud by the researcher in the pre-tests. However, the results of the posttests indicate that Ben answered one more problem correctly when he read the posttest independently. These results could be due to the fatigue that Ben exhibited during the last session as described in the qualitative results section.

4.3.2 Qualitative Results

Analysis of the anecdotal notes taken during the eight sessions showed that Ben was on task during 99% of the intervals. He was observed watching what another student was doing only twice, during the very first session. He was observed using the text-to-speech engine for extra help with the problems during 5% of intervals. Ben requested assistance from the researcher during 27% of the intervals across the eight sessions attended. Ben asked for assistance the most on step 6 (Answer the Question) of the problem solving process, as it related to the "units" in question. A specific example of this demonstrated difficulty can be seen with the following problem taken from Ben's tutorial session #3.

Question: Tammy and Jimmy both bought candy at the store. They started with 10 pieces of candy. Tammy and Jimmy ate a total of 4 pieces of candy. How many pieces of candy are left?

The correct answer for "units" in Step 6 was "pieces of candy". Ben was observed typing in the following words for "units": pieces, store, they, started, with, of, a, total, left, bought, money, many, Tammy, and candy. This is a clear indication that Ben was not conceptualizing what the word “units” meant. He started typing in each word in the word problem trying to see if it was correct. Other examples from other problems are: units = servings and he typed in “dollars” and “servings he ordered”, also units = beats per second and he typed in “humming birds’, “beats”, and “beats its wings”. He also had difficulty in understanding that “how much change will he get?” refers to money. Ben did not demonstrate any difficulty in solving multi-step problems during the Addition/Subtraction module, however, he was observed building equations in the Multiplication/Division module using addition.

Ben was observed during the tutorial sessions reading along with the text-to-speech engine each time a new word problem was presented. He used the headphones during every session and was observed with them on during session 5 when the text-to-speech engine was unavailable due to a computer malfunction. When told that he would not be able to hear anything through the headphones for that session he simply stated, “I know”.

He had to repeat the introduction to the Addition/Subtraction module but this did not seem to frustrate him in any way, he just began the introduction again without any comments or non-verbal demonstrations of frustration. Ben did attempt on one occasion to use the bypass icon to bypass the seven-step process but was unsuccessful in correctly answering the question in the time allotted and was directed back to the first step of the seven-step process. He was not observed using this component in any future sessions. Ben did not demonstrate any verbal displays of frustration during any of the sessions. He did however, demonstrate affirmation during a session when he was overheard stating, “I got it. I got it this time!”

Ben was enthusiastic and cooperative during each of the sessions. There were no verbal outbursts during any of the sessions but it was noted that during student interactions prior to each of the sessions he was very bossy, aggressive, and quick to reprimand a student for what he considered an infraction; and yet he exhibited very quiet concentrated behaviors during the tutorial sessions. When he would ask for assistance from the researcher during the sessions it was very matter of fact and specific and usually involved Step 6 of the problem solving process. He also asked the researcher for assistance in defining the following words: operation, owe, units, tenths, and rounding.

Because of the computer malfunction during session 5, the talking avatar, the text-to-speech engine, and the live tutors were unavailable. Therefore, data on the uses of these embedded devices for this student was only obtained for 7 sessions.

In the interviews across the sessions Ben responded “yes” to having used the talking avatar (to hear the text in the text box read aloud) for 4 of 7 sessions. In the beginning, Ben attributed the use of the talking avatar to “needed help and advice on the units”, but by the end of the sessions he responded with “no, I understood it more and more as I went through the process”. The data from Table 13 indicate that Ben’s avatar use per problem decreased after session #3, but fluctuated considerably after that. The text-to-speech engine was only used 3 of 7 sessions. Ben explained that he used the text-to-speech engine because “I really didn’t understand the problem the first time”. He explained he didn’t use the text-to-speech engine “because I can read the problem by myself”. Ben was not observed using the live tutors during any of the sessions. His responses for the question regarding what went well for the session were, “that I passed the test on the second try”, “I got more points”, “I got through the levels” and “I got through most of my problems with only a little bit of problems and not like with any major problems”. Getting motivational points was very important to Ben. He felt that for the most part everything went well. He responded to the question about what didn’t go well today with the following; “When I didn’t pass the test on the first time. I was paying attention but I kinda didn’t get some stuff”, “On the third problem I kept on putting in the wrong words for the units”, “Like when I got stuck on one unit because I didn’t spell it right”, “Like when I couldn’t get the problem and had to go to the text-to-speech engine. Makes me feel dumb because the other kids didn’t have to do that”, and “that I got stuck on a problem for awhile”. Ben thought that the other students would look down on him if he needed to use the support systems embedded in the cognitive tutoring system.

4.3.3 Summary for Ben

It appears as though the use of the embedded devices within this cognitive tutoring program, specifically the use of the audio support system, played an important part in Ben’s success because he was able to complete more problems and modules than either of the other two students. Analysis of the data pertaining to his PSSA scores in Math indicate that he was proficient, yet Ben's score (1358) was much lower than Adam's score (1434) on that assessment. Both Ben and Adam scored a descriptive rating of average on the TOMA-2 indicating that Ben was not more proficient in math before beginning the intervention sessions. Consistent with his decoding and fluency difficulties, Ben relied on the use of the text-to-speech engine to read the problems aloud to him, only asking for assistance from the researcher in defining vocabulary words not decoding them. He did not use the live interactive support from teachers therefore, whether this device would have contributed to greater success can not be determined.

4.4 CHARLIE

Charlie is a 10 year old fifth grader whose teachers describe as lacking motivation because he is slow to respond or react to teacher inquiries. In informal interviews with his teachers it was noted that they were never sure whether he comprehended what was going on in class, although when called upon to answer a question he responded correctly most of the time. He was often observed looking intently at the board or his book during instruction. When teamed with other students he did not appear to be an active participant. One teacher noted that she had observed him sitting on the bleachers at a soccer game and attempted to engage him in conversation about the exciting game he was watching. She said that Charlie appeared unaffected.

Charlie's pre-assessment subtest results for the TOMA-2 are listed in Table 16.

Table 16: TOMA-2 Results-Charlie

Subtest	Raw Score	Percentile Rank	Standard Score	Descriptive Rating
Computation	11/30	37th	9	Average
Story Problems Read Independently	2/25	5th	5	Below Average
Story Problems Read Aloud by Researcher	6/25	25th	8	Average

The results of the computation subtest indicate that Charlie was average and did not have any computation difficulties, never the less; he was the lowest scorer of the three students. The data also indicate that he was not very competent at problem solving but when the story problems were read aloud to Charlie there was a noticeable increase in his performance.

Charlie's subtest results for the reading pre-assessments are listed in Table 17.

Table 17: MAZE-CBM, DIBELs ORF, and CORE Phonics Survey Results-Charlie

Assessment	Score	Descriptive Rating
MAZE- CBM	9	Below Target
DIBELs ORF	43	At Risk
CORE Phonics Survey		
Short vowels CVC words	8/10 (80%)	Low Risk
Short vowels, digraphs, and –tch trigraph	8/10 (80%)	Low Risk
Consonant blends with short vowels	14/20 (70%)	More direct instruction needed
Long vowel spellings	7/10 (70%)	More direct instruction needed
Variant vowels and diphthongs	8/10 (80%)	Low Risk
R- and I- controlled vowels	8/10 (80%)	Low Risk
Multisyllabic words	8/24 (33%)	More direct instruction needed

The reading results indicate a difficulty with reading comprehension as measured by the MAZE-CBM, a fluency difficulty as measured by the DIBELs ORF and decoding difficulties specifically in the areas of multisyllabic words, consonant blends with short vowels, and long vowel spellings as measured by the CORE Phonics survey.

4.4.1 Charlie's Tutorial Sessions

Charlie attended seven of the eight tutorial sessions missing session 3 due to an illness. The results for the number of problems attempted during each session, the number of problems answered correctly, and the number of problems answered incorrectly along with the module he was in during each session are listed in Table 18.

Table 18: Class Problems Completed-Charlie

Session #	# of problems attempted	# of problems correct	# of problems incorrect	Module
1	Introduction			
2	1	0	1	Add/Sub
3	Student was absent			
4	3	3	0	Add/Sub
5	4	4	0	Add/Sub
6	6	6	0	Add/Sub
7	9	9	0	Add/Sub
8	4	4	0	Add/Sub

Charlie was the slowest of the three students in working through the computer program. He was successful in completing only 27 of the 32 problems in the Addition/Subtraction module in the eight sessions available. He took the entire first session and most of the second session to complete the introduction. The computer malfunction during session #5 which resulted in the students not being able to access the text-to-speech engine did not seem to have an adverse affect on Charlie's pace through the module. He was able to correctly answer 96% of the problems attempted.

Charlie's results for the number of avatar helps during each session is listed in Table 19.

Table 19: Total Avatar Helps per Session (Addition/Subtraction only)-Charlie

Session #	# of Problems Completed	# of Avatar Helps	# of Avatar Helps per Problem Completed
1	Introduction	Introduction	Introduction
2	1	52	52.0
3	Student absent	Student absent	Student absent
4	3	14	4.7
5	4	21	5.3
6	6	32	5.3
7	9	18	2.0
8	4	16	4.0
Total	**27**	**153**	**5.7**

The data indicate that Charlie used the avatar the most during session #2 although he only completed one problem. A more thorough description of the areas of difficulty in the seven-step problem solving process encountered by him are listed in Table 20. Charlie took approximately 30 minutes at the beginning of session #2 to complete the introduction to the computer program. During the remaining 30 minutes of session #2 Charlie was observed attempting to answer the first question of the Addition/Subtraction module. He was unable to answer the only question he attempted during session #2 correctly.

Table 20: Avatar Helps per Problem-Solving Step Results (Add/Sub only)-Charlie

Session #	# of Problems Completed	Step 2 Define The Goal	Step 3 Identify the Variables	Step 4 Build the Equation	Step 5 Solve the Equation	Step 6 Answer the Question	Total Avatar Helps per Session	# of Avatar Helps per Problem Completed
1	Intro	Intro	Intro	Intro	Intro	Intro	Intro	Intro
2	1	7 (13%)	25 (48%)	6 (12%)	3 (6%)	11 (21%)	52	52.0
3	Student absent	Student absent	Student absent	Student absent	Student absent	Student absent	Student absent	Student absent
4	3	0	2 (14%)	9 (64%)	2 (14%)	1 (7%)	14	4.7
5*	4	0	2 (10%)	2 (10%)	0	17 (81%)	21	5.3
6	6	0	8 (25%)	12 (38%)	1 (3%)	11 (34%)	32	5.3
7	9	1 (6%)	2 (11%)	11 (61%)	2 (11%)	2 (11%)	18	2.0
8	4	0	6 (38%)	6 (38%)	1 (6%)	3 (19%)	16	4.0
Total	**27**	**8 (5%)**	**45 (29%)**	**46 (30%)**	**9 (6%)**	**45 (29%)**	**153**	**5.7**

* indicates no text-to-speech engine or talking avatar during this session.

The data results from Table 20 indicate that Charlie had the most difficulty with Steps 3, 4, and 6, with the avatar uses evenly divided among the 3 steps (unlike Adam and Ben). Charlie demonstrated the most difficulty with Step 3 (Identify the Variables) during session #2, with nearly half of his total avatar usage for the intervention session being used for this one step.

The data also indicate that Charlie had the most difficulty with Step 6 (Answer the Question) during session #5. This could be attributed to the lack of the text-to-speech engine due to a computer malfunction; he was observed using his finger to follow under the words in the problem as he read silently. Charlie demonstrated the most difficulty with Step 4 (Build the Equation) during sessions #4 and #7. Although the number of problems he completed in session #7 was three times the number he completed in session #4, the percentage of avatar usage for this step was nearly the same. Coincidentally the level of difficulty of the problems increased in session #7, yet he was able to complete more problems than in session #4.

Charlie was unable to complete an entire module during the tutorial sessions he attended. Although the reports indicate that he did not use the one-on-one tutoring available through the live interactive support from teachers, he was observed using the interactive support on one occasion.

The posttests were administered after the last tutoring session. Charlie scored 50% correct on the 10 posttest questions read independently and 40% correct on the 10 posttest questions read aloud by the researcher. These data indicate that he was somewhat more successful when he read the problems independently. Because Charlie was only able to complete 27 of the 32 problems within the Addition/Subtraction module during the tutorial sessions attended, an analysis of the questions about Addition and Subtraction was conducted. The results of Charlie's pre-tests (TOMA-2) were compared to his posttests. Results from both the pre-tests (TOMA-2) and the posttests are listed in Table 21.

Table 21: Analysis of Results on Addition/Subtraction Problems-Charlie

TOMA-2 Read independently by the student (n = 13)	TOMA-2 Read aloud by the researcher (n=13)	Posttest B Read independently by the student (n=4)	Posttest A Read aloud by the researcher (n=4)
2 (15%)	6 (46%)	3 (75%)	1 (25%)

Results from the pre-tests read both independently by the student and read aloud by the researcher were compared to the posttests read both independently by the student and read aloud by the researcher. The data from Charlie's pretests indicate that he was more successful when the problems were read aloud to him by the researcher. However, the results of the posttests indicate that Charlie answered 3 of 4 problems correctly when he read the posttest independently.

4.4.2 Qualitative Results

Analysis of the anecdotal notes taken during the sessions Charlie attended is based on 84 intervals of observational data. Charlie was observed being on task 100% of the time. He was observed using the text-to-speech engine for extra help during 4% of the intervals. He requested assistance from the researcher during 15% of the intervals, (less than either Adam or Ben) for the entire seven sessions attended. Charlie was observed staring intently at the screen and did not ask for assistance from the researcher until approached. During one session, Charlie was observed attempting to use the bypass icon to bypass the seven-step problem solving process. He was unable to successfully complete the problem during the allotted time and was directed back to the first step of the process for that problem. He was not observed attempting to use the bypass icon during future sessions.

The only verbal display of frustration that Charlie demonstrated was during the second session when he had to repeat the introduction because he had failed to answer the post-introduction questions correctly and this came in the form of a “sigh”. He demonstrated no verbal displays of affirmation during any of the sessions. Charlie is a very quiet and reserved child and appeared pensive throughout the sessions he attended. He was observed touching the computer screen with his fingers to follow along with the text being read to him by the talking avatar.

Like the other two students Charlie was observed having difficulty with the word “units” in step 6 of the problem-solving process. Some of the examples of this observed difficulty are: units = miles; he typed “how many miles”, units = pies; he typed “how many pies”, units = dollars; he typed “change”, units = dollars; he typed “money”. When asked by the cognitive tutoring system to “Build the Equation (step 4), he was observed typing the problem backwards and at one point was typing in words for the equation rather than numbers.

In the interviews across the sessions Charlie responded “yes” to having used the talking avatar (to have the text in the text box read aloud) for 2 out of 6 sessions. He said he attributed his use of the talking avatar to “the questions were hard and I didn’t understand them” and that he did not need to use the talking avatar because “it kept popping up and telling me what I did wrong”. He stated that he used the text-to-speech engine for 2 of 6 sessions. He credited the use of the text-to-speech engine to “there was a big word and I couldn’t read it” and “Because there was a big word and I couldn't sound it out". Charlie explained that he did not use the text-to-speech engine "because the words were little baby words and I am getting better at it and faster at it". He used the live tutor device only once during the seven sessions that he attended because he "wanted to see what it was like". Charlie's responses to the question regarding what went well for the session were; "when I knew there was a live tutor, because if I didn't understand it they would help me", "when I got a couple of them done", "that I kept on going and got my units right", and "that I got a lot of smart points, they are important to me". Although he did not demonstrate any non-verbal forms of frustration other than a "sigh", when asked the question regarding what did not go well for you today he was more talkative than the others. His responses included: "when I checked on the test I missed and had to start the whole thing over", "when I knew that we had to go on the computers-having to read the problem by myself-some words are really big and those are the words that help me understand the problem-but it didn't help me to have what I did wrong written at the bottom", "that I didn't have to use the live tutor-I really wanted to use it-because I think it would be cool to talk to someone when I needed help", and "I couldn't-like I was going so fast I got stuck on the units".

4.4.3 Summary for Charlie

Although Charlie did not present any challenges for the researcher, he was the student that the researcher was most concerned about during the study. Because he did not show any signs of frustration, it made it more difficult to discern his areas of need. His pensive staring at the computer screen during the tutorial sessions reflected his inability to comprehend the word problems, suggesting that his reading difficulties were impeding his math word problem solving abilities.

Charlie's use of the talking avatar during two of the sessions indicates that he was having difficulty in understanding the text. Although he used the live interactive tutor once during a session his use was not attributed to need but because to wanting to see what it was like to use the live tutor. He had difficulty with the same three steps as the other students did but no particular difficulty in any one of the steps. Analysis of whether he was able to apply the seven-step problem solving process to independent work outside of the computer program could not be determined by the posttests because he did not show all his work in the spaces provided on the posttests.

4.5 CROSS CASE-STUDY COMPARISON

These three students had varying levels of reading difficulties. Adam had difficulty with comprehension, Ben had difficulty with both fluency and decoding, and Charlie had difficulty with comprehension, fluency and decoding.

Teachers have reported to the program developers (information obtained through an informal conversation with an Apangea representative) that during a regular classroom session (45-50 minutes long) a student of average mathematical ability can complete a lesson and 5 to 6 problems per session. Therefore an average student should be able to complete 40 problems during eight 45-minute sessions. Based on the above information the average number of problems that should have been completed over the eight 60-minute sessions is 52. Because all three students took longer than expected to complete the introduction, (1½ sessions) the researcher took this into consideration and did not include the first 1½ sessions into the analysis of the data regarding the number of problems that they should have completed during their sessions. The analysis of the number of problems they should have completed is based on 6½ sessions for Ben, and 5½ sessions for both Adam and Charlie because they both were absent for one session. Based on the information provided by the program developers and analysis of the data, Ben should have completed 42 problems total across the sessions that he attended. Ben completed a total of 69 problems during the sessions that he attended indicating that his performance using this cognitive tutoring program was above average. Adam and Charlie should have completed 34 problems across the sessions they attended. Adam completed a total of 32 problems and Charlie completed a total of 27 problems indicating that they were both just slightly under average.

Because Ben was the only student to finish more than one module of the cognitive tutoring program the multiple case-study comparison of the avatar use during each step of the seven-step problem solving process focused only on the Addition/Subtraction module. The Addition/Subtraction module contains four levels that increase in difficulty with eight word problems per level for a total of thirty-two questions within the module. Charlie was only able to complete 27 of the 32 problems in the Addition/Subtraction module during the sessions he attended. Both Adam and Ben completed the Addition/Subtraction module. (See table 22 below).

Table 22: Total Modules and # of Problems Completed for Adam, Ben and Charlie

Students	Modules Completed	Total # of Problems Completed
Adam	Addition/Subtraction	32
Ben	Addition/Subtraction Multiplication/Division	31 38
Charlie	none	27

The reports for Ben only account for 31 of 32 of the problems he completed in addition/subtraction module and 38 of 40 problems he completed in the multiplication/division module. The computer program would not allow the students to advance to the next module unless they had completed all of the problems in the previous module. This deletion of one problem in the addition/subtraction module and the deletion of two problems in the multiplication/division module could be attributed to a computer malfunction.

The seven-step problem-solving process embedded in this cognitive tutoring system was an integral component of the program. Steps 1 and 7 are not part of the report because the problem is read to the students by the text-to-speech engine in step 1, and step 7 requires the students to explain their answer. The chart below illustrates the distribution of avatar helps across the problem-solving steps for each student in the Addition/Subtraction module.

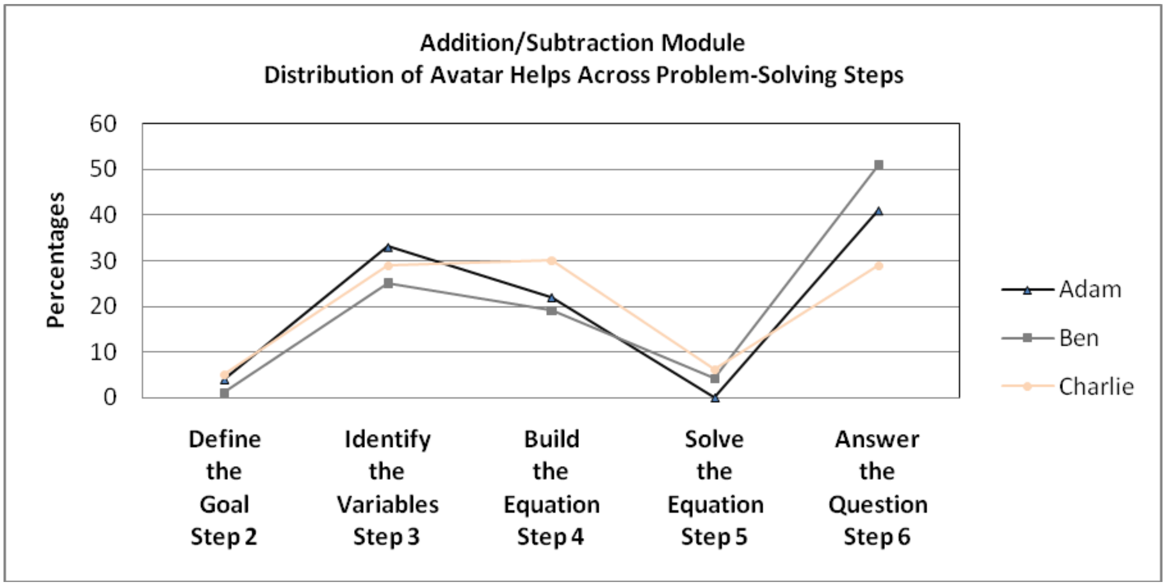

Figure 2: Distribution of Avatar Helps per Problem Solving Step Across Students

The data illustrate that all the students had relatively the same percentage of avatar helps for Step 2 and Step 5; less than 10%. The data also illustrate that both Adam and Ben had the most difficulty with Step 6 and less difficulty with Steps 3 and 4. However, Charlie's percentage of avatar uses was equally divided among Steps 3, 4 and 6. It was observed by the researcher that the difficulty with Step 6 pertained to the word "units" that was required to answer the question. All students were observed as having answered the problem correctly, they just had difficulty in identifying the "units".

Both Adam and Charlie were identified through the pre-assessments as having reading comprehension difficulties. A comparison of the above data regarding the percentage of avatar use shows that Adam had a higher percentage of avatar usage for Steps 6 and 3, but less usage for Step 4 than did Charlie. The avatar icon was automatically triggered each time a student typed in an incorrect answer in the space provided.

Both Ben and Charlie were identified through the pre-assessments as having both decoding and fluency difficulties. However, despite Ben's decoding and fluency problems his pace in this cognitive tutoring program was much faster than either Adam or Charlie. A comparison of the above data demonstrates that although Ben was able to identify the variables and build the equation more readily than Charlie was, he was less able to identify the "units" used in answering the question.

The use of the embedded devices within this cognitive tutoring system differed among these students. (See table 23 below).

Table 23: Total Use of the Embedded Devices for All Sessions by Adam, Ben, and Charlie

Devices	Adam	Ben	Charlie
Text-to-speech engine	3 times	4 times	3 times
Talking Avatar Icon	5 out of 6 sessions attended	4 out of 7 sessions attended	2 out of 6 sessions attended
Live Interactive Tutors	2 times	0 times	1 time

The table above indicates the students' use of three different embedded devices. The text-to-speech engine is an icon that when activated by the students (clicking on it) will reread the problem aloud to the students. The talking avatar icon will appear at the bottom of the screen with a text box when triggered by an incorrect answer entered by the student. The students have the option of clicking on the icon to have the information in the textbox read aloud to them or reading the information independently. The live interactive tutor device was activated when a student entered a number of incorrect answers (based on the default number set by the system administrators) for the problem solving step.

Ben's use of this device may have assisted him in successfully completing more word problems by alleviating the decoding and fluency issues he had, however his use of this device was not significantly greater than that of Adam or Charlie who both completed fewer problems. The talking avatar icon would appear with a computerized hint in a textbox when the students entered an incorrect answer in the space provided. The students could click on the talking avatar and have the computerized hint read to them or they could read it independently. Because it was a personal choice for each student, it is difficult to discern if the use of this device had a positive effect on the problem solving skills of these struggling readers. The assistance of the live interactive tutors was used by both Adam and Charlie, not because they needed the help but because they wanted to see what it was like to use the live tutors.

The researcher also observed the differences among Adam, Ben, and Charlie with respect to how often they asked the researcher for assistance and also how often they were observed being on task during the sessions. This information is listed in Table 24.

Table 24: Assistance and On-Task Differences for Adam, Ben, and Charlie

	Adam	Ben	Charlie
Asked Researcher for Assistance	25%	27%	15%
On-task	68%	99%	100%

Adam was observed being on-task the least amount of time of all three students. The difference in the percent of time he asked the researcher for assistance compared to Ben is not significant. This difference in the amount of time on-task compared to both Ben and Charlie could be due to his inability to concentrate because of his diagnosed ADHD, and the end of the school day when his medicine was wearing off. Charlie was observed being on-task 100% of the time during the sessions he attended. He also asked the researcher for assistance the least number of times during those sessions. Although, Ben asked the researcher for assistance more often than did Adam or Charlie, they all asked the researcher for assistance when they were having difficulty identifying the “units” within the problem.

4.6 SUMMARY

There were similarities in what the students brought to the sessions. All three participants scored average on the computation portion of the TOMA-2 indicating that they had the computation skills required for use with this cognitive tutoring system. Each of the participants also increased their scores on the story problem subtest of the TOMA-2 when the problems were read aloud to them by the researcher indicating that listening was a factor in their success.

There were also some differences in how they approached working with the Apangea system. Both Adam and Charlie used the assistance of the live tutors not because they needed to have the help, but because they wanted to, as is evidenced by Charlie’s comment “That I didn’t have to use the live tutor-I really wanted to use it because I think it would be cool to talk to someone when I needed help”. However, Ben did not use the assistance of the live tutors. Adam often took off his headphones and read the problems independently; Charlie used the headphones for most of the sessions attended and Ben used them on a regular basis. Ben was the only student to use the audio support system on a regular basis during the tutoring sessions. Charlie used the audio support system for most of the sessions he attended, but Adam rarely used this device. A noteworthy difference among these students was in the speed at which they worked throughout the sessions. This is evidenced by the number of modules and problems completed by each student. (Refer to Table 22, page 69).

Another similarity among these students was in their inability to correctly identify the "units" within the word problems presented to them in this cognitive tutoring program. Although disappointing, the results for the posttests may have been different had the posttests been given on a day when the students did not complete a full hour long intervention session.

With regard to the seven-step problem solving process, all the students struggled with conceptualizing what "units" meant with regard to the specific word problems. Misspelling the word used to identify the units in the problem (i.e. dollers for dollars) was deemed as the wrong answer by the program, prompting the students to believe they had identified the wrong word for "units" causing even more confusion. It also could not be determined if the seven-step process could be applied to independent work outside of the computer program since the students did not show all their work in the spaces provided on their posttests.

The data indicate that all the students increased their raw score and percentile scores on the TOMA-2 when the word problems were read aloud by the researcher compared to the students reading them independently. However, two of the three students failed to increase their scores on the posttests read aloud by the researcher compared to the posttest read independently. Both students, Ben and Charlie, were tired and anxious to have the last session over. By the time they had gotten to the second posttest they both were displaying signs of fatigue and a lack of motivation.

5.0 FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter discusses the findings and summarizes the conclusions drawn from the analysis of data. A discussion of the related issues and implications for use in classroom instruction, and limitations are included. Finally, recommendations for future research in this area are discussed.

5.1 FINDINGS

The findings for each of the research questions are as follows:

Question #1:

In what ways did the use of an audio support system and other learning devices embedded in this cognitive tutoring system, facilitate the word problem solving skills of struggling readers?

The embedded devices did facilitate the word problem solving skills of these struggling readers during the cognitive tutoring sessions. Reading barriers were reduced or removed and the program allowed for individualization, permitting each student to proceed at his own pace. The students appeared to be successful, solving most problems correctly, but at the same time the cognitive tutoring program doesn't allow for error, so a determination of whether there was conceptualization with regard to their math word problem solving abilities can not be made.

Question #2:

Were there significant differences in how these embedded devices were utilized by the individuals who were identified as having existing decoding, fluency, and/or comprehension difficulties?

There were differences in how these embedded devices were utilized by the students. Specifically these were: Ben used the audio support system during every tutorial session it was available, Charlie used it during most of the sessions and Adam rarely used this device. There were also some similarities: All three students had difficulty with step 6 (Answer the Question) of the problem solving process, specifically when asked to identify the "units" within the problem, and it appeared as though there was limited scaffolding to help them with this particular step. Both Adam and Charlie used the live tutor device not because they needed assistance but because they wanted to see what it was like to use a live tutor, however, Ben did not use the live tutors. Although the uses of the various devices within this system were different, the analysis of the data did not indicate that there was a significant difference comparatively in how these devices were used throughout the study.

Question #3:

What differences were there in the students' performance when the pre and post math word problem tests were read to them as compared to when the students read and complete the items?

The results of the pretests of math word problems (TOMA-2) indicated that all of the students increased their scores when the test was read aloud to them by the researcher compared to when it was read independently. Though all the students did increase their scores when the TOMA-2 was read aloud to them by the researcher, this increase was not significant.

At the same time, there were minimal differences noted when the posttest problems were read aloud to the students compared to when the students read and completed them independently. Adam increased his score by one question when the problems were read aloud and both Ben and Charlie decreased their scores by one question.

Question #4:

How successful were the students in learning from this cognitive tutoring system?

Whether these students were successful in learning from this cognitive tutoring system is inconclusive. The program is written in such a way that it is expected that students using this cognitive tutoring system will solve the problems correctly and they did so. The devices embedded therein made it almost impossible for the students to fail. The question remains as to whether the students can be successful at math word problems during regular classroom instruction when they do not have the assistance of a cognitive tutoring program that identifies their mistakes immediately and guides them to successfully complete the problem.

5.2 CONCLUSIONS

The purpose of this multiple-case study was to investigate the use of a support system in which the math text is read to the students through the use of a text-to-speech engine (audio support system) embedded in a cognitive tutoring system. This multiple-case study design allowed the researcher to observe the participants throughout the tutorial sessions.

It was important to have all three students begin in the same module so that comparisons with regard to how each participant used the audio support system and other devices embedded in the cognitive tutoring system could be made. Although all the participants began with the same module, on the same level, they worked independently during the tutorial sessions at their own pace. The pace of all three students differed throughout the study. Ben completed the greatest number of problems and modules throughout all the sessions and was observed using the embedded devices regularly. Although Adam completed more problems than Charlie, Adam was observed using the embedded devices the least amount of time during the sessions.

Several conclusions were drawn from this study. *First, a computer based program that provides support through various learning devices such as a talking avatar for listening and a problem solving process, can enable students' success within the tutoring sessions.* Computer based programs can provide opportunities for differentiation given the various embedded devices. Specifically, in this program, the availability of the talking avatar which provided listening support seemed to be useful to the students. Also, this program provided a seven step problem solving approach to help students understand how to solve math word problems. In the following sections, each of these is discussed.

As mentioned previously, students did better on the pretests when the story problems were read to them than when they read them independently; this is similar to what Tindal et.al. (1998), found in their study. Their results indicated that the students with IEP's in both math and reading performed better on the test when it was read aloud to them. However, there was no significant difference in the performance of the students without IEP's who were given the same accommodations. None of the students in this study had disabilities that required an IEP; however, they did have difficulties in reading in the areas of comprehension and/or fluency, and decoding. In this study the fact that the students increased performance on the story problem subtest when the test was read aloud to them by the researcher is important because it again supports the notion that by removing the reading barrier a more accurate demonstration of their performance on math word problems could be determined. Although results on the posttest did not confirm the importance of listening as a support for struggling readers, with several students scoring less well when the material was read to them, there were outside extraneous factors that most likely affected these results. One student had experienced a particularly frustrating day and came to the last tutoring session appearing on edge and unfocused. The other two were more concerned with the after session pizza party than participating in the last tutorial session.

Cognitive tutoring programs containing embedded listening devices can be a source of support for students with reading difficulties. In this study there was variability in the manner in which the text-to-speech engine was used by the students. The observational data demonstrated that the text-to-speech engine was used more by the students with the decoding and fluency difficulties than by the student who had comprehension difficulty only, during the tutorial sessions. The student who had decoding and fluency difficulties used the text-to-speech engine more often than the other two students and he was able to complete more problems during the tutorial sessions than the other two students. Clearly, the use of the text-to-speech engine was a source of support for this student.

The seven-step problem solving process is one approach to addressing story problems. Other researchers have devised other approaches to solving such problems. Jitendra et al. (1998) conducted a study that compared the use of a schema based strategy and the traditional basal strategy to determine how they affected the problem solving abilities of students with mild disabilities. In the schema based approach the students were provided with the tools necessary to sort problems into groups requiring the same problem solving skills. In the traditional basal strategy a guided discovery strategy (i.e. read the problem, plan, organize, and solve the problem) was used. The researchers found that the students who were provided with the schema strategy scored higher than those who were provided with the traditional basal strategy, and that the students with mild disabilities benefited most from the schema based strategy.

The cognitive tutoring system in this study used a combination of both the schema based strategy and the traditional basal strategy. This computer program has the problems sorted into groups requiring the same problem solving skills, within the levels of difficulty, within each of the modules. The seven-step problem solving process is consistent with the traditional basal strategy. However, this cognitive tutoring program separates the "organize" step of the traditional basal strategy into both steps 3 and 4, "Identify the Variables" and "Build the Equation" respectively. It also adds two more steps to the process step 6, "Answer the Question" and step 7, "Explain Your Answer". Step 6 of this problem solving process proved to be the most confusing and difficult step for the students in this study. This confusion was in part due to the inflexibility of the program, specifically with regard to misspelled words, and the students' inability to correctly identify a "unit". Although the students were requested to explain their answer in step 7 of the problem solving process before they could advance to the next problem, their inability to do so or their misspelling of any words did not hinder their advancement.

The students were required to follow each step to complete the word problems presented. This cognitive tutoring system does allow the students to attempt to solve the problems without going through the seven-step process by clicking on a bypass icon giving students approximately 45 seconds to answer the question on their own without the use of the seven-step process. If students are unsuccessful they are directed back to the first step of the seven-step process. Each of the students were observed attempting to bypass the seven-step process for one problem, but were unsuccessful in completing the problems and were directed back to the seven-step process. This indicates that the students could not complete the problems without the use of the seven-step problem solving process and that it was essential to their achievement.

Jitendra et al. (1999), conducted another study to determine if the schema based strategy affected the progress from solving one-step word problems to solving two-step word problems in students with learning disabilities and also the effects of maintaining the strategy over time. The results of that study indicated that there was significant improvement in the problem solving skills of all the students on the one-step word problems. The results also showed an increase in the problem solving skills of 3 of the 4 students on the two-step word problems. Another study of importance was the study conducted by Fuchs and Fuchs (2002). In this study the researchers attempted to describe the problem solving abilities of students with math disabilities with or without comorbid reading disabilities. Three types of word problems were used for this study; arithmetic, complex, and real-world. These three types increased in difficulty level and progressed from concrete to abstract. The results of their study indicate that as the difficulty level of the problems increased, student scores decreased.

The present study contained aspects of both of the two studies listed above with the use of a cognitive tutoring system that combines the strategies of a problem solving approach with the use of multi-step word problems. The reports generated after each session provided information regarding the performance of the students. However, one important aspect of information that could not be obtained through these reports was the number of avatar helps based on the level of difficulty of the problems. The Addition/Subtraction module contains four levels of difficulty with eight questions per level (Refer to Appendix B). So a conclusion as to whether the students in this study benefitted from the strategies and the multi-step problem solving process could not be determined because these reports do not distinguish between one-step word problems and multi-step word problems, unlike in the study by Jitendra et al. (1999) where the researchers worked with the students and were thus able to discern whether students had difficulties with one or two step word problems and where those difficulties appeared.

An important aspect of this cognitive tutoring program is that the students are required, through the levels of difficulty within the module, to successfully complete one, two and three step word problems before being allowed to advance to another module. If they have not demonstrated success by achieving the required mastery within that level the computer will automatically present the students with the problems missed. If the students fail to achieve success again the computer will present all the problems within the level to the students until they have been successful. Although this is an integral component of this cognitive tutoring system it did not have to be utilized by the students in this study. However, this component parallels the re-teaching for understanding practiced in many classrooms today.

In other words, these devices enabled students to succeed in doing their math word problems. However, they differed in their pace, they used the avatar at different times, and certainly this is an advantage of a computer based program. At the same time, the data obtained did not provide evidence to determine if this computer based program facilitated the conceptual understanding necessary to solve math word problems. Certainly, the few number of sessions and the small sample limit any generalization about this, but it provides information about the need for additional research.

A second conclusion is that a computer based tutorial program can provide on-going support for the students and the opportunity for practice. It provides the students with the practice that is necessary for a complete understanding of the word problems, it provides for independent pacing during the tutorial sessions and has additional devices such as the text-to-speech engine that can support learning; however it can not be used by itself to teach students how to solve word problems. Because the system identifies the area of the problem that needs correction the students are not required to independently find their mistakes.

In a study conducted by Fuchs et al. (2003), they attempted to assess the effects of explicitly teaching for transfer. They combined a transfer treatment with instruction called a transfer-plus-solution instructional method and compared it to both teacher designed instruction and instruction on word problem solutions alone. They used explicit instruction, intense practice of examples, and peer- mediated practice during the sessions. The researchers attempted to teach the students in their study to master problem solving rules, sort problems into like categories, and recognize related problems so that they could transfer the skills from one problem to another. They used pre and posttests for their assessments. They found that the students who received the transfer treatment showed significantly more improvement than those in the control group, and that those students who were present for all sixteen sessions improved more than the students who did not receive the transfer treatment. In addition they found that the students with disabilities did not improve as much as the researchers expected when given the partial solution-plus-transfer method. The explicit teaching of problem solving rules and intense practice of examples from their study compares to the present study because the computer program uses explicit instruction through the use of a seven-step problem solving process and intense practice of examples presented to each student in the modules to teach problem solving skills. Based on the data obtained it is expected that the students would improve in their ability to be successful at solving word problems.

The present study attempted to ascertain whether the students in this study would be able to apply the seven-step problem solving process to independent work through the use of posttests that paralleled the questions they were presented by the cognitive tutoring program. The researcher was seeking to determine the effectiveness of the tutorial program on the abilities of the students to apply their learning to independent work. It was found in this study that the students were successful in applying the seven-step problem solving process to the questions on the posttests that related to the Addition/Subtraction module.

5.3 DISCUSSION

Using a cognitive tutoring program to supplement classroom instruction can both enhance and impede a child's learning. This cognitive tutoring program was specifically designed to be used as a supplement to classroom instruction. The version used in this study was the Apangea Learning Math 4.0. Since this study was completed a newer version (Math 5.0) of this program has been designed and adapted for use in schools. It was reported that the newer version (5.0) addresses some of the concerns that were identified in the present study. One concern with regard to the program was the identification of the word "unit" in Step 6 (Answer the Question) of the problem solving process. The 4.0 version of this cognitive tutoring program required the students to use correct spelling when answering step 6 of the problem solving process as it related to "units". Although this was a requirement within the system, there was no indication to the students that the word they had entered was misspelled and the avatar icon would appear with a textbox and inform the students that they had identified the wrong units. This only added to the confusion and frustration of the students. The newer version of the program does not require the students to identify the word "units".

The scaffolding of the seven step problem-solving process enhanced the students learning because it built upon the previous step to provide support through the problem-solving process. However, the difficulties that the students encountered, specifically with the word "units", impeded their ability to smoothly transition from step 6 of the problem solving process to step 7, and the subsequent completion of the problem. Each of the students in this study spent a vast amount of time during each tutoring session focusing on the identification of the "units" in the problem. The removal of this aspect of step 6 of the problem solving process should enable students to focus more on identifying the variables to be used to build the equation and less time on an aspect of the problem that has no effect on the expected outcome.

Although related research has shown that vocabulary instruction plays an important role in the conceptual understanding of math word problems, this study did not provide strong evidence to support such findings. Past research has demonstrated that vocabulary meaning appears to be important in solving math word problems, and in addition, it also appears to be a source of difficulty for struggling readers. According to Carnine and Silbert (1979), expository text is more apt to contain more technical vocabulary related to the content area. Beck, et.al., (2002) refer to this type of vocabulary as a third tier word where the use of the word is minimal and area specific.

Capraro and Joffrion (2006), found that mathematical content reading requires that students understand the meanings of words. One purpose of their study was to examine factors that may be affecting student learning. They did so by examining two multiple choice questions and one short answer question from pre/post assessments using two parallel forms of an algebra test to see how students translated the words into algebraic equations. The students who were randomly chosen were asked to explain their reasoning for their answers. The results of their study yielded a more complete understanding of how students think and reason when translating mathematical words to symbols. The researchers found that vocabulary plays an important role in the understanding of mathematics.

In the present study, all students demonstrated difficulty in comprehending the meaning of the word "unit" as it related to each question. This vocabulary word was defined and explained to the students during the introduction phase of the cognitive tutoring system yet consistently throughout the sessions the students struggled with this one word and its meaning. Although the "units" themselves were different in each word problem, the concept of what a "unit" is remained constant. The students' conceptual understanding of the word "units" was not improved by simply providing them with the definition. Although, misspelling of the word identifying the “units” in the problem and the system’s subsequent rejection of their answer because of the misspelling required the students to submit another answer, their lack of conceptualization of the word was apparent. Although Charlie stated that he used the talking avatar in a couple of sessions because “the questions were hard and I didn’t understand them” (Refer to Qualitative Results for Charlie), he did not ask the researcher for assistance with any vocabulary. This lack of conceptualization by the students of this particular word certainly establishes the importance of a specific concept important to mathematics. At the same time, the students did not appear to have problems overall with vocabulary in the text that they were provided. The fact that this cognitive tutoring systems program was written at a 4th grade reading level and provided both auditory and visual support to the students may have lessened the impact of vocabulary knowledge or conceptualization on the students’ ability to solve these word problems.

Cognitive tutoring system reports are an important tool for identifying a students’ area of instructional need. This cognitive tutoring systems reports provide in-depth information about a student’s performance in the various levels within the modules completed. The information obtained from the reports enables teachers to examine specific steps of the problem solving process to determine areas in which the students may need additional instructional support. This information is vital in determining conceptual misunderstandings that students may be having when completing word problems.

However, an area of concern that arose during this study was that the reports generated by this cognitive tutoring system did not contain all of the necessary information needed to assess the students’ performance. One important aspect of information that could not be obtained through these reports was the number of avatar helps based on the level of difficulty of the problems. It was expected that this information would be made available in the reports, however, the reports generated after each session did not contain this specific information. The researcher took anecdotal notes at five minute intervals throughout the sessions, therefore, it was not possible to observe all three students to ascertain the level of difficulty of the problem and how many times the students used the avatar for help with each problem. Another important piece of information that could not be obtained from the reports was what the students wrote in response to step 7 (Explain your answer) of the problem solving process. This information would have been helpful in understanding how the students conceptualized the problem and arrived at their answers.

Math cognitive tutoring programs can be an important asset to supplement classroom instruction. They provide students with the much needed practice of solving word problems; allowing the students to progress at their own pace. The embedded devices within the system such as the talking avatar, the text-to-speech engine, and the steps to the problem solving process are designed to assist the students and aid in their successful completion of the modules. However, there are difficulties that arise when using computer programs. First, when using a cognitive tutoring program similar to the one used in this study the computer technology in the schools has to be up to date. Internet programs may need to be installed on the computers that the students will use so that they will have access to the embedded devices within the cognitive tutoring program. Lastly, the inability to obtain the required reports impedes the assessment of the effectiveness of the program on student achievement. Teachers need to be able to rely on the data within the reports to assist them in making instructional decisions on individual students as well as the class as a whole.

Math cognitive tutoring programs can be a motivational component to assist students in practicing their word problem solving skills. The students in this study appeared excited to use this program and were eager to get started in each of the sessions. Two of the students remained on task during the sessions. Although the third student did not appear to be on task, his diagnosed ADHD could have been a factor; he came to the sessions just as excited about getting started each session as the other two students. The seven-step problem solving process allowed the students to see their own progress thereby motivating them to be successful and encouraging them to continue practicing their word problem solving skills.

5.4 LIMITATIONS

One limitation of this study was the problems associated with technology use. The school computers had to be equipped with internet capabilities. On several occasions when certain technology requirements needed by the students to be able to use the system were removed from the computers by the technology department, the researcher had to download them again. The inability to download certain technology requirements needed for internet use accounted for the incapability of the students to use the text-to-speech engine on one occasion.

Another limitation of this study was that there was some missing information in the reports generated with regard to one of the students; not all of the problems completed during the session were accounted for in the reports. It was also expected that the researcher would have access to the transcripts of the communication between the live tutors and the two students who utilized this device for assistance with a problem. The reports indicated that there were no data available.

Another limitation of this study was the small number of participants. A larger number of participants identified with specific reading difficulties would have been helpful in making a more in-depth and extensive comparison of their uses of the embedded devices.

5.5 RECOMMENDATIONS FOR INSTRUCTION

Although the cognitive tutoring system seems to be an effective approach for providing ongoing practice and individualization, it appears that students would benefit from direct instruction from the classroom teacher who can help the students to review their work and identify their own mistakes, make the necessary corrections and bring about a more thorough understanding of the problem solving process. Reliance on the computer program to identify the students' mistakes and direct them to attempt another answer, does not mean that a conceptualization of what was being asked in the word problems has taken place.

Second, it would be helpful if the teachers would use the seven-step word problem solving process in their classroom instruction when the students are going to be using this cognitive tutoring program. The students need to be taught how to transfer what they learned on the computer to independent work in the classroom. Posttests performance can be an indicator of whether transfer has taken place. If the students do not demonstrate success in their performance on the posttests, the teacher may need to review the seven-step process with the students individually or in a small group to determine the students' area(s) of need.

5.6 RECOMMENDATIONS FOR RESEARCH

Further research in the area of cognitive tutoring systems and their effectiveness as a teaching tool is needed. One type of study might be an experimental study, with an experimental and comparison group of students using the same or similar cognitive tutoring system to determine if the system had any effects on the struggling readers who have been identified with specific reading difficulties. The use of the embedded devices could be controlled providing a more definitive answer as to the effects these devices have on the word problem solving performance of struggling readers.

Another type of study is one that would compare the effectiveness of the computer program to classroom instruction using the same seven-step problem solving process with struggling readers who have been identified with specific reading difficulties. It would be important to determine if the intervention provided by the use of the seven-step problem solving process within a classroom setting and administered by a teacher, would yield the same effects as the use of the cognitive tutoring system to provide the same intervention without the personal connection.

Further research in the area of math word problem solving should be conducted to determine any resulting areas of need struggling readers might demonstrate, that is hindering their word problem solving performance in the classroom.

APPENDIX A

PARENTAL CONSENT FORM

PARTENTAL CONSENT TO ACT AS A SUBJECT IN A RESEARCH STUDY

TITLE: **Cognitive Tutoring Systems: A study of the use of an audio support system and its effects on the problem solving abilities of struggling readers**

PRINCIPAL INVESTIGATOR: Eileen St. John, Graduate Student
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The purpose of this research is to study if students do better at solving math story problems when they work with a computer tutoring system that reads problems to them. 50 fifth grade students from Uniontown School District will be asked to take part in this research study. If you let your child join this study, he/she will be asked to do 14, 1-hour tutoring sessions on a computer at school.

- All students will be screened before the tutoring sessions for math and/or reading troubles. This will take about 1 hour.
- Then students will be put into one of two groups randomly (by chance). Students in both groups will work on the computer to solve math problems. The students in group 1 will have the problems read to them. Students in group 2 will not have the problems read to them.
- After the 14 tutoring sessions are done your child will do two tests to see how well they can do story problems on their own.

There is little risk involved in this study. One risk is that children may get frustrated when working on math problems. This is common. If your child gets frustrated I will talk with them when the math problems are done. Another possible risk is loss of privacy. Everything possible will be done to protect your child's privacy.

It will not cost anything for your child to join the study. When your child is done with all the sessions he/she will get a $10.00 Border's gift card. This study is completely voluntary.

Any information about your child taking part in this study will be kept private in a locked file cabinet. Nobody will know your child joined the study. The principal and teachers will not be told how your child did on the tests and tutoring sessions.

If you have any questions about this study you can call the researcher on the first page of this consent form. If you have questions about your child's rights while they are in this study, please contact the Human Subjects Protection Advocate at the University of Pittsburgh IRB Office at 1-866-212-2668.

****

PARENTAL CERTIFICATION

- I have read the consent form for this study and any questions I had, have been answered to my satisfaction. A copy of this consent form will be provided to me.
- I understand that I am encouraged to ask questions about this study during at any time, and that those questions will be answered by the researchers listed on the first page of this form.
- I understand that my child's participation in this study is strictly voluntary and that I can refuse to have my child participate or remove my child from the study at any time without any effects.
- I agree to have my child participate in this study.

______________________________	______________________________	______________
Child's Name (PLEASE PRINT)	Parent's Signature	Date

(Parents please do not sign below this line)

****

I certify that I have carefully explained the purpose and nature of this research study to the child in age appropriate language. He/She has had an opportunity to discuss it with me in detail. I have answered all of his/her questions and he/she has provided affirmative agreement (i.e. assent) to participate in this study.

Assent for participation ______________________________ ____________

Investigator's Signature Date

University of Pittsburgh
Institutional Review Board

Approval Date:
Renewal Date:

IRB #:

APPENDIX B

COURSE DESCRIPTION: ADDITION AND SUBTRACTION

In this module the students can review and practice the fundamentals of addition and subtraction. Students are introduced to the terms sum and difference and the concept of addition and subtraction as inverse operations. Addition and subtraction problems are first demonstrated on number lines and progress to vertical forms. Place value and regrouping are also discussed and practiced. Students are required to solve problems using basic addition and subtraction.

Level	**Description**	**Equation**
1	You will begin by finding the sum or difference of two numbers.	$x = a + b$
2	In this level, we will find the sum or difference of three numbers.	$x = a + b + c$
3	In this level, you will use the addition and/or subtraction to find the answer.	$x = a + b - c$
4	In this final level, you will use addition and/or subtraction to solve for a group of numbers.	$x = a + b - c + d$

Sample Problem:

Sara and Jayna did a Walk-a-thon for their 6th grade class. Sara walked 3 miles on Saturday afternoon, and Jayna walked 2 miles on Sunday morning. Together, how many miles did both of the girls walk?

APPENDIX C

COURSE DESCRIPTION: MULTIPLICATION AND DIVISION

In this course, students will practice using the essential operations of multiplication and division. Multiplication is emphasized as repeated addition and the multiplication table is used as a tool to solve problems. Sharing and grouping is used to illustrate division. The various symbols used to represent multiplication and division are discussed, as well as inverse operations. Also, the commutative, associate, and distributive properties are introduced. Students will solve problems using multiplication and division separately as well as together.

Level	Description	Equation
1	You will begin by multiplying two numbers in order to get a product.	x = a* b
2	In this level, you will find the quotient of two numbers.	x = a / b
3	In this level, you will find the product of three numbers.	x = a * b * c
4	In this level, you will find the quotient of a group of three numbers.	x = a / b / c
5	In the final level, you will find the answer to a problem involving multiplication and division.	x = a * b / c

Sample Problem:

Bob was making a model of his house for a project. He used graph paper to make it more accurate. He was drawing the pantry and it was 12 squares long by 13 squares wide. How many total spaces did the pantry take up?

APPENDIX D

COURSE DESCRIPTION: DECIMALS

Students are required to extract pertinent information, formulate an equation, and solve the equation to answer the questions correctly. Questions range in difficulty from the addition of two positive decimal numbers to more complex operations involving combining the addition, subtraction, multiplication, and division of decimal numbers. Many problems involve the use of percents as decimals in finding the sales taxes and sales commissions.

Level	Description	Equation
1	You will begin by adding decimals.	x = a + b + c
2	In this level you will find the change after buying 2 items.	x = c – a – b
3	In this level you find the change after buying several items.	x = c – (a * b)- (d * e)
4	In this level you will convert a percent to a decimal and use it to find change from a purchase.	x = (a + b + c) – p * d
5	In the final level of Decimals, you will calculate gross weekly pay by adding base pay to earned commission.	x = b + p * (c – d)

Sample Problem:

Sandra sells advertisements for a newspaper. She has a base salary of $250 a week plus 10% of all her sales over $500. Last week she sold $1,250 in advertisements. What was her salary last week before tax deduction?

APPENDIX E

POSTTEST A

Original Question #1:

Timothy has 2 hamsters and they recently had babies. The mother hamster had 6 babies. How many hamsters does Timothy now have?

Revised Question #1:

Johnny has 2 rabbits and they recently had babies. The mother rabbit had 4 babies. How many rabbits does Johnny now have?

Original Question #2:

Alison, Owen, Shea are going to the store to buy snacks for a party at school. They have $20 to buy food and drinks. Owen buys chips for $4. Alison and Shea buy drinks for a total of $10. How much money will they get back?

Revised Question #2:

Billy, Jason, and Bob are going to the store to buy snacks for an after school party. They have $18 to buy food and drinks. Jason buys chips for $6. Billy and Bob buy drinks for a total of $8. How much money will they get back?

Original Question #3:

Tara is buying two shirts. One shirt is $8 and one shirt is $14. She is also returning a pair of pants that cost $19. How much does Tara owe?

Revised Question #3:

Jay is buying two T-shirts. One T-shirt is $7 and one T-shirt is $14. He is also returning a pair of shorts that cost $13. How much money does Jay owe?

Original Question #4:

Aretha has to run 25 laps around the gym each week for Gym class. On Tuesday she ran 8 laps, and on Wednesday she ran 9 laps. On Thursday, Mr. Jogalot told Aretha that she cut the corners on 3 of her laps and she had to do them over. How many laps did Ashley have to run on Thursday?

Revised Question #4:

Tim has to run 20 laps around the gym each week for Gym class. On Wednesday he ran 6 laps, and on Thursday he ran 8 laps. On Friday, Mr. Jones told Tim that he cut the corners on 4 of his laps and he had to do them over. How many laps did Tim have to run on Friday?

Original Question #5:

Gregory is coaching a little league team this year and his team won their first playoff game. He decided to take them all to the Dairy Duke for ice cream. There were 15 players on his team and he got them each a medium ice cream cone. Each cone was 2 dollars. How much money did Gregory spend on ice cream cones?

Revised Question #5:

Pam is coaching a girl’s softball team this year and her team won their first playoff game. She decided to take them all to Chuck’s Creamery for banana splits. There were 15 players on her team and she got each of them a banana split. Each banana split was 2 dollars. How much money did Pam spend on banana splits?

Original Question #6:

Johnny was walking home from school with two friends. He found an instant lottery ticket lying beside the road. To his surprise, when he looked at the ticket, he had won 24 dollars. He decided he would split it 3 ways between himself and his two friends. How much money will each boy get?

Revised Question #6:

Jennifer was walking home from the library with two friends. She found an instant lottery ticket lying on the sidewalk. When she looked at the ticket, she had won 18 dollars. She decided she would split the winnings 3 ways between herself and her two friends. How much money will each kid girl get?

Original Question #7:

Mountain Top high school is having their annual dance marathon to raise money for their community. This year, there are 56 people that are participating. The average time dancing for each person is 22 hours and they all receive around 5 dollars per hour dancing. How much money will this dance marathon bring in?

Revised Question #7:

Western Middle School is having their annual dance marathon to raise money for a charity. This year, there are 48 people that are participating. The average time spent dancing for each person is 18 hours and they all receive 4 dollars per hour dancing. How much money will this dance marathon bring in?

Original Question #8:

This week was Craig's turn to bring drinks for his soccer team. He bought two large cases of sports drinks giving him a total of 90. There are 15 people on his team and they each drink 2 sports drinks per game. How many games will these drinks last?

Revised Question #8:

This week was Brian’s turn to bring drinks for his basketball team. He bought two large cases of sports drinks giving him a total of 84. There are 14 people on his team and they each drink 3 sports drinks per game. How many games will these drinks last?

Original Question #9:

Dean was the star of his soccer team. In the first game of the season, he scored 3 goals. By the halfway point, his goal total was 8 times that. If half a season is 12 games, how many goals did he have to average per game?

Revised Question #9:

Jason was the star of his baseball team. In the first game of the season, he scored 4 homeruns. By the halfway point, his homerun total was 6 times that. If half a season is 12 games, how many homeruns did he have to average per game?

Original Question #10:

Collin eats at Great Burger. He orders a burger for $4.35. He orders fries for $1.01. He orders a drink for $0.98. How much money does Collin owe in all?

Revised Question #10:

Tanika eats at Burger Barn. She orders a cheeseburger for $3.75. She orders fries for $1.20. She orders a drink for $.86. How much money does Tanika owe?

APPENDIX F

POSTTEST B

Original Question #1:

Sara and Jayna did a Walk-a-thon for their 6th grade class. Sara walked 3 miles on Saturday afternoon, and Jayna walked 2 miles on Sunday morning. Together, how many miles did both of the girls walk?

Revised Question #1:

Emily and Paul did a walkathon for their 4th grade class. Emily walked 2 miles on Saturday afternoon, and Paul walked 4 miles on Sunday morning. Together, how may miles did both of them walk?

Original Question #2:

Roseanne bought two tickets to the movie “Awesome Racer”. She bought an adult's ticket for $6, a children's ticket for $3, and paid with $20. How much change will Roseanne get back?

Revised Question #2:

Jennifer bought two tickets to the movie, “Daddy Daycare”. She bought an adult’s ticket for $6, and a children’s ticket for $2, and paid with a $20. How much change will Jennifer get back?

Original Question #3:

Tamika took her little sister shopping with her and bought her lunch. Tamika bought a drink for $2 and her sister bought a sandwich for $4. Tamika had a coupon for $1 off a sandwich. What is the total of Tamika's food and drink bill?

Revised Question #3:

Robin took her little brother shopping with her and bought him lunch. Robin bought a drink for $3 and her brother bought a sandwich for $5. Robin had a coupon for $1 off a drink. What is the total of Robin’s food and drink bill?

Original Question #4:

Holly is 9 years old and collects rocks. She had 93 rocks. She lost a bag with 26, gave 11 to her friend, found 8 more and threw out 4. How many rocks does Holly have now?

Revised Question #4:

Janie is 11 years old and collects marbles. She had 86 marbles. She lost a bag with 28, gave 13 to her friend, found 9 more and threw out 4. How many marbles does Janie have now?

Original Question #5:

Sean never did any chores around the house. When the leaves began to fall from the trees this year, his dad told him he had to rake the yard. Instead he called 6 of his friends and told them that he would pay them each 5 dollars to do it for him. How much money would he have to pay?

Revised Question #5:

Billy never did chores around the house. When the snow began to fall this year, his dad told him he had to shovel the driveway. Instead he called 4 of his friends and told them that he would pay them each 6 dollars to do it for him. How much money would he have to pay?

Original Question #6:

Each year during spring, Ron helps his parents plant new flowers in the back yard. He is given 36 flowers that he has to divide evenly among 4 different areas in his back yard. How many flowers will be planted in each area?

Revised Question #6:

Each year during spring, Patty helps her grandmother plant new flowers in her backyard. She is given 30 flowers that she has to divide evenly among 6 different areas in her grandmother's backyard. How many flowers will Patty plant in each area?

Original Question #7:

Francine is trying to put away some spending money for college. For every hour she works this summer, she is going to put away 4 dollars. This summer, she will work an average of 23 hours a week for 11 weeks. How much money did she put away for college?

Revised Question #7:

Jason is trying to put away some spending money for college. For every hour he works this summer, he is going to put away 4 dollars. This summer, he will work an average of 23 hours a week for 11 weeks. How much money did he put away for college?

Original Question #8:

In order to prepare for the upcoming year, Chuck ordered 360 notebooks for the creative writing class he was teaching. He had a total of 6 classes with 15 people in each class. How many notebooks did he have for each person?

Revised Question #8:

In order to prepare for the upcoming year, Robin ordered 320 folders for the art class she was teaching. She had a total of 5 classes with 16 people in each class. How many folders did she have for each person?

Original Question #9:

Cassandra and Lynette were calculating the number of points they scored on the basketball team last season. Cassandra scored 40 points. Lynette scored 3 times that amount. If there were 15 games in the season, how many points did Lynette average per game?

Revised Question #9:

Rob and Bill were calculating the number of points they scored on the basketball team last season. Rob scored 30 points. Bill scored 4 times that amount. If there were 15 games in the season, how many points did Bill average per game?

Original Question #10:

Eric wants to make cookies. He goes to the store and buys a pound of butter for $2.38. He buys a dozen eggs for $0.96. He buys a bag of chocolate chips for $2.87. How much does Eric spend at the store?

Revised Question #10:

Stu wants to make brownies. He goes to the store and buys a pound of butter for $1.98. He buys a dozen eggs for $0.75. He buys a bag of chocolate chips for $3.02. How much does Stu spend at the store?

BIBLIOGRAPHY

Adams, T. L. (2003). Reading mathematics: More than words can say. *The Reading Teacher*, 56: 786-795.

Adams, T.L. & Lowery, R.M. (2007). An analysis of children's strategies for reading mathematics. *Reading and Writing Quarterly*, 23: 161-177.

Aiken, L.R. (1972). Language factors in learning mathematics. *Review of Educational Research,* 42: 359-385.

Anderson, R. C., & Pearson, P., D. (1984). A schema-theoretic view of basic processes in reading. In P. D. Pearson (ED.), *Handbook of reading research* (255-292). New York: Longman.

Apangea Learning (2006). *Apangea Learning: Bringing Learning to Life.* [Brochure].

Beck, I. L., & McKeown, M. G. (1989). Expository text for young readers: The issues of coherence. In Lauren B. Resnick, (Ed.), *Knowing and Learning and Instruction*, (pp.47-65). Hillsdale, NJ: Erlbaum.

Beck, I. L., McKeown, M. G., & Kucan, L. (2002). *Bringing Words to Life: Robust vocabulary instruction.* New York: Guilford Press.

Beck, I. L., Sandak, R., and Perfetti, C. (2003). Focusing attention on decoding skills for children with poor reading skills: design and preliminary tests of word building intervention. *Scientific Studies of Reading*, Vol. 7 (1): 75-104.

Borasi, R., Siegel, M., Fonzi, J., & Smithe, C.F. (1998). Using transactional reading strategies to support sense-making and discussion in mathematics classrooms: An exploratory study. *Journal for Research in Mathematics Education*, 29: 275-305.

Capraro, M. M., & Joffrion, H., (2006). Algebraic equations: Can middle-school students meaningfully translate from words to mathematical symbols? *Reading Psychology*, 27: 147-164.

Carnine, D. & Silbert, J. (1979). *Direct instruction reading.* Columbus, OH: Merrill.

Carter, T. A., & Dean, E. O., (2006). Mathematics intervention for grades 5-11: Teaching mathematics, reading, or both. *Reading Psychology,* 27: 127-146.

Fuchs, L. S., & Fuchs, D.,(2002). Mathematical problem solving profiles of students with mathematics disabilities with and without comorbid reading disabilities. *Journal of Learning Disabilities,* Vol. 35, 6:563-573.

Fuchs, L. S., Fuchs, D., Prentice, K., Burch, M., Hamlett, C.L., Owen, R., Hosp, M. & Jancek, D., (2003). Explicitly teaching for transfer: Effects on third-grade students' mathematical problem solving. *Journal of Educational Psychology,* Vol. 95, 2:293-305.

Good, R.H. & Kaminski, R.A. (Eds.). (2002b). *Dynamic Indicators of Basic Early Literacy Skills (6th Edition).* Eugene, OR: Institute for the Development of Education Achievement. Retrieved March 26, 2007 from: http://dibels.uoregon.edu/

Goodman, K. S. (1992). I didn't find whole language. *Reading Teacher,* 46 (3): 188-199.

Gough, P. B. (1996). How children learn to read and why they fail. *Annals of Dyslexia,* 46: 3-20.

Gough, P., & Juel, C., (1991). The first stages of word recognition. In L. Rieben and C. A. Perfetti (eds.), *Learning to read: Basic research and its implications* (pp. 47-56). Hillsdale, NJ: Erlbaum.

Gunn, B., Biglan, A., Smolkowski, K. & Ary, D. (2000). The efficacy of supplemental instruction in decoding skills for Hispanic and non-hispanic students in early elementary school. *The Journal of Special Education*, Vol 34, 2: 90-103.

Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading and Writing: An Interdisciplinary Journal,* 2: 127-160.

Jitendra, A. K., Griffin, C. C., McGoey, K., Gardill, M. C., Bhat, P., & Riley, T., (1998). Effects of mathematical word problem solving by students at risk or with mild disabilities. *The Journal of Educational Research,* Vol 91, 6: 345-355.

Jitendra, A. K., Hoff, K. & Beck, M.M., (1999). Teaching middle school students with learning disabilities to solve word problems using a schema-based approach. *Remedial and Special Education,* Vol. 20, 1: 50-64.

Kane, R. B., Byrne, M. A., & Hater, M. A. (1974). *Helping children read mathematics.* New York: American Book Company.

Konold, T., Juel, C., McKinnon, M., Deffes, R. (2003). A multivariate model of early reading acquisition. *Applied Psycholinguistics,* 24: 89-112.

Meyer, B. J. F., & Rice, G. E. (1984). The structure of text. In R. Barr, M.L. Kamil, P. Mosenthal, &P.D. Pearson (Eds.), *Handbook of Reading Research*, Vol.1. New York: Longman.

Meyer, T. N., Steuck, K., Miller, T. M., & Kretschmer, M., (2002). *Multi-year large-scale field studies of the fundamental skills training project's intelligent tutoring systems.* Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Miles, M.B., & Huberman, A. M., (1994). *Qualitative Data Analysis.* Second Edition. Thousand Oaks, London, New Delhi: Sage Publications.

Mitchell, J. M., (2001). Interactions between natural language and mathematical structures: The case of "wordwalking". *Mathematical Thinking and Learning*, vol.3, 1:29-52.

Monroe, E. E., Black, S., & Buhler, A. J., (2002). *Examination of oral retellings of word problems by third grade students.* Paper presented at the Organization of Teacher Educators in Reading.

Moats, L. (Eds.). (2000). *Speech to Print*. Baltimore, London, Sydney: Paul H. Brookes.

National Council of Teachers of English. (n.d). *Learning Through Language: A call for action in all disciplines.* Retrieved March 26, 2007 from: http://www.ncte.org/about/over/positions/category/curr/107630.htm. (Language)

National Reading Panal. (2000). *Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction.* Washington, DC: National Institute of Child Health and Human Development.

Oakhill, J., & Uuill, N. (1996). Higher order factors in comprehension disability: Processes and remediation. In C. Cornoldi & j. Oakhill (Eds.), *Reading comprehension difficulties*. 69-92. Mahwah NJ: Lawrence Erlbaum Associates, Inc.

Papalia, D. E., & Olds, S. W., (1998). *Human Development.* Boston, Burr Ridge, Dubuque, Madison, New York, San Francisco, St. Louis: McGraw.

Perfetti, C. A., (1985). *Reading Ability.* New York: Oxford University Press.

Rasinski, T. V. (1990). Effects of repeated reading and listening-while-reading on reading fluency. *Journal of Educational Research*, Vol. 83, 3:147-150.

Readence, J. E., Bean, T. W., & Baldwin, R. S. (2001). *Content Area Literacy: An Integrated Approach.* Dubuque: Kendell/Hunt.

Schleppegrell, M. J., (2007). The linguistic challenges of mathematics teaching and learning: A research review. *Reading and Writing Quarterly,* 23: 139-159.

Stanovich, K. E. (1991). Discrepancy definitions of reading disability: Has intelligence led us astray? *Reading Research Quarterly,* 26, 7-29.

Tindal, G., Heath, B., Hollenbeck, K., Almond, P., and Harniss, M., (1998). Accommodating students with disabilities on large-scale tests: an experimental study. *Exceptional Children.* 64 (4): 439-446.

Thompson, D. R., & Chappell, M.F. (2007). Communication and representation as elements in mathematical literacy. *Reading & Writing Quarterly,* 23: 179-196.

Wheeler, J. L., & Regian, J. W.(1999). The use of a cognitive tutoring system in the improvement of the abstract reasoning component of word problem solving. *Computers in Human Behavior,* 15: 243-254.

Wolfe, M. B. W., (2005). Memory for narrative and expository text: Independent influences of semantic associations and text organization. *Journal of Experimental Psychology: Learning Memory and Cognition.* Vol. 31, 2: 359-364.

Yin, R. K., (1994). *Case Study Research: Design and Methods.* Second Edition. Thousand Oaks, London, New Delhi: Sage Publications.