PRINCIPLES AND METHODOLOGY FOR
COMPUTER ASSISTED INSTRUCTION (CAI) DESIGN

by

Janna Margurette Crews

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SIGNED: Janna M. Crews

Janna M. Crews
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# TABLE OF CONTENTS

LIST OF FIGURES ........................................................................................................... 10
LIST OF TABLES ............................................................................................................. 11
ABSTRACT ..................................................................................................................... 12

CHAPTER 1 – INTRODUCTION .................................................................................... 14
    Purpose of the Study ................................................................................................. 15
    Development of the Design Principles ..................................................................... 16
    Overview .................................................................................................................... 16

CHAPTER 2 – BACKGROUND ON LEARNING AND INSTRUCTION ......................... 18
    Learners ..................................................................................................................... 20
        Active Participation ............................................................................................... 20
        Cognitive Effort .................................................................................................... 21
    Instructional Methods ............................................................................................. 22
        Multisensory Learning ......................................................................................... 22
        Expository Learning ............................................................................................ 23
        Mastery Learning ................................................................................................. 24
        Timely Feedback .................................................................................................. 25

CHAPTER 3 - BACKGROUND ON CAI DESIGN ......................................................... 28
    Active Participation of the Learner .......................................................................... 29
    Issues of Cognitive Load .......................................................................................... 30
        Focus Attention .................................................................................................... 31
        Minimize distractions ........................................................................................... 31
        Reduce Anxiety .................................................................................................... 31
    Multiple Perceptual Modalities .............................................................................. 32
    Expository Learning ................................................................................................. 32
    Mastery Learning ..................................................................................................... 33
    Feedback .................................................................................................................. 33
        Personalized ......................................................................................................... 34
    CAI Evaluation Matrix ............................................................................................ 35
# TABLE OF CONTENTS - Continued

**CHAPTER 4 – RESEARCH APPROACH** .................................................. 37  
Triangulation ...................................................................................... 38  
Selecting Methodologies .................................................................. 38  
Selected Approach ........................................................................... 39  
  Review .............................................................................................. 39  
  Case Study and Field Study .......................................................... 41  
  Principles and Methodology .......................................................... 41  
  CAI Evaluation Matrix ................................................................. 42  
  Prototyping ..................................................................................... 42  
  Field Experiments .......................................................................... 43  
Conclusion ......................................................................................... 43  

**CHAPTER 5 – PILOT STUDY AND FIELD STUDY: METHODS, ANALYSIS AND RESULTS** .................................................. 44  
The Pilot Study .................................................................................. 45  
  The CAI Program: Larrabee's Bridge to Adult Literacy .................. 46  
    The Lessons ................................................................................. 48  
  Pilot Study Results ......................................................................... 49  
    DRP Scores ................................................................................ 49  
    Teacher Interview .................................................................. 50  
    Interview with the Reading Specialist ................................. 51  
    Student Interviews .................................................................. 51  
Discussion ......................................................................................... 59  
The Field Study ................................................................................ 60  
Research Design .............................................................................. 61  
  Participants .................................................................................. 61  
  Treatments – Independent Variables ........................................ 62  
  Assignment to Treatments ............................................................ 62  
  Measures – Dependent Variables .............................................. 70  
  Hypotheses .................................................................................. 77  
  Procedures .................................................................................. 78  
Analysis ............................................................................................ 82  
  DRP Scores ................................................................................ 82  
  Structured Student Interviews .................................................... 84  
  Oral Readings .................................................................................
TABLE OF CONTENTS - Continued

Results ................................................................................................................................. 85
  DRP Scores ................................................................................................................... 85
  Structured Student Interviews ..................................................................................... 87
  Oral Readings ............................................................................................................... 94
Discussion ......................................................................................................................... 95

CHAPTER 6 – CAI DESIGN PRINCIPLES & METHODOLOGY .................. 96

CAI Design Principles for Improving Learning ......................................................... 96
  Principle 1: Integrate instruction, practice, assessment and feedback .................. 96
  Principle 2: Instruct ..................................................................................................... 97
  Principle 3: Practice .................................................................................................... 99
  Principle 4: Assess ....................................................................................................... 101
  Principle 5: Feedback ................................................................................................. 101
  Principle 6: Support mastery learning ....................................................................... 103
  Principle 7: Focus cognitive effort ............................................................................. 104
  Principle 8: Personalize CAI ..................................................................................... 105
    Personalize Instruction, Practice, Assessment and Feedback ............................. 105
    Provide Learner Controls ....................................................................................... 106
    Provide Administrative Controls .......................................................................... 107
  Principle 9: Learner-centered design ....................................................................... 108

A Methodology for CAI Design .................................................................................. 109

CHAPTER 7 – A CASE OF DESIGNING CAI: AGENT99 TRAINER. 123

Introduction to Agent99 Trainer CAI system ............................................................ 124
  Watch Lecture module .............................................................................................. 124
  View Examples with Analysis .................................................................................. 127

Designing Agent99 Trainer ....................................................................................... 129

Testing of Agent99 Trainer Prototype ..................................................................... 143

Evaluations of Agent99 Trainer ................................................................................ 144
  Can People Be Trained to Better Detect Deception? Instructor-led vs. Web-based Training .......................................................... 144
  Agent99 Training: Designing a Web-based Multimedia Training System for Deception Detection Knowledge Transfer ........................................................................... 145
  Training to Detect Deception: An Experimental Investigation .......................... 147
TABLE OF CONTENTS - Continued

User Experience with Agent99 Trainer .......................................................... 152
Conclusion ........................................................................................................ 156
CHAPTER 8 – CONCLUSIONS ...................................................................... 157
Implications ..................................................................................................... 159
Opportunities for Future Research ............................................................... 160
  Review of Existing CAI ........................................................................ 161
  Field Study ............................................................................................. 161
  Agent99 Prototype ................................................................................. 162
    Web-based CAI - Anytime, Anyplace .................................................. 162
    CAI Design Methodology .................................................................. 163
    Longer Courses .................................................................................... 163
    Other Issues ........................................................................................ 164
APPENDIX A - ACRONYMS ......................................................................... 165
APPENDIX B - TERMS AND DEFINITIONS ........................................... 166
APPENDIX C - STRUCTURED STUDENT INTERVIEW
  QUESTIONNAIRE ..................................................................................... 171
REFERENCES ............................................................................................... 178
LIST OF FIGURES

Figure 1: Instructional System ................................................................. 19
Figure 2: CAI Instructional System - Designing CAI to Support Learners and Learning ................................................................. 29
Figure 3: Evaluation Matrix for CAI Features ........................................ 36
Figure 4: Framework for a Multimethodological Approach to IS Research (Nunamaker 1992) ........................................................................ 38
Figure 5: Inter-rater Reliability: Accuracy Ratings on Sample by Raters 1 & 2 .... 81
Figure 6: Inter-rater Reliability-Acceptability Ratings on Sample by Raters 1 & 2 ..... 82
Figure 7: Repeated Measures Analysis of DRP Test Scores for Treatment vs. Control . 86
Figure 8: Watch Lecture module ................................................................. 125
Figure 9: Watch Lecture module – Example drop-down menu ......................... 126
Figure 10: View Examples With Analysis module ........................................ 127
Figure 11: View Examples With Analysis – Example and expert analysis displayed .. 128
Figure 12: Deception detection accuracy scores for control vs. combined treatment groups and for the combined sample (Figure 1) ........................................ 150
LIST OF TABLES

Table 1: Multimethodological Research Approach of this Study ........................................... 39
Table 2: Results of Paired Sample t-Test on DRP Instructional Scores and NCEs ............. 51
Table 3: 4-point Response Scale for Student Interview Questionnaire .............................. 75
Table 4: Oral Reading Passages .......................................................................................... 76
Table 5: Structured Student Interviews – Closed-ended Items 1-24 ................................... 88
Table 6: Structured Student Interviews – Closed-ended Items 25 to 47 ............................ 89
Table 7: Student Open-ended Responses to Item 10 ....................................................... 91
Table 8: Student Evaluation of Multisensory Activities .................................................... 93
Table 9: Results of Paired Sample t-Test on Oral Reading Ratings ............................... 95
Table 10: Detection Accuracy Means as a Function of the treatment and time factors ................................................................. 145
Table 11: Participants Responses in the Usability Test (Questionnaire) ......................... 146
Table 12: Means and standard deviations (in parentheses) for knowledge pretests and posttests. (Table 2) ........................................... 148
Table 13: Means and standard deviations (in parentheses) for accuracy pretests and posttests (Table 3) ........................................................................ 148
Table 14: Means and standard deviations (in parentheses) for judgment and knowledge pretests and posttests for Session 2, comparing Agent99 to lecture and combination treatment groups. (Table 4) ........................................... 149
ABSTRACT

As the role of computer-assisted instruction (CAI) rapidly expands in the educational and training efforts of all types of organizations, the need for well-designed, learner-centered CAI continues to grow. The CAI design principles and methodology proposed herein provide systems designers with a framework for designing effective, learner-centered CAI systems that support learning with information technologies. Implementing the framework should lead to CAI that better supports learners in the development of their mental schemas, and ultimately, in achieving their learning objectives.

The primary goals of this research are two-fold. First, derive a theoretically and empirically-based set of CAI design principles directed at purposefully exploiting the unique capabilities of information technology to help learners develop their mental schemas. Second, codify a methodology for implementing these principles in the systems analysis and design process. Both goals are accomplished as follows.

First, a literature review was undertaken to uncover features important for designing CAI to improve learning. Concurrently, the design features and functionality of several existing CAI were reviewed. A field study of one distinctive CAI was conducted to investigate and substantiate its effectiveness. Results indicated that learners using the CAI improved their achievement significantly more than learners who did not use the CAI did. Moreover, learners attributed their improved performance to using the CAI. Based on the literature review, review of existing CAI, and the results of the field study, a set of principles and a methodology for designing CAI were derived. The design
principles and methodology focus the CAI design process on supporting learners’
development of their mental schemas. Finally, we designed, developed and implemented
a prototype web based, multimedia training system in accordance with the proposed CAI
design principles. As a partial instantiation of the proposed principles and methodology,
this prototype CAI provides a proof-of-concept. The design and effectiveness of the
prototype CAI has been tested in a series of experiments. The corroborating evidence
from these studies indicates that the prototype CAI is well-designed, usable, and an
effective training tool. The demonstrated success of the prototype provides evidence of
the merits of the proposed principles and methodology.
CHAPTER 1 – INTRODUCTION

Using electronic technologies for education is not a new concept, but the types of technologies predominant in the classroom have changed. Twenty to thirty years ago, overhead projectors, 35mm slide projectors, 16mm film projectors, televisions, and video players/recorders were among the most common (Heinich et al. 1996). In 1977, microcomputers began appearing in schools (Roblyer 1997). During the last 30 years, the educational use of computers in the classroom and for training has grown at an increasing rate. With that growth, the design of computer assisted instruction (CAI) became an important research issue. Moreover, in the late 1990’s, as the Internet became ubiquitous technology, interest in CAI, web-based learning and distance-learning became widespread. Today, individuals, businesses, educational institutions and government organizations all have an interest in using, designing, and/or implementing CAI.

Sweeping technological changes and the changing nature of the workforce makes effective learning and training imperative for the success of both individuals and organizations. Although some learning may occur without conscious or intentional effort, learning and mastering most knowledge and skills requires concerted effort on the part of the learner. Improving learning is important to individual learners to help them achieve their learning objectives while making the most effective use of their time and effort. Correspondingly, organizations need a well-educated, skilled workforce that can adapt to the changing workplace. Thus, improving the learning process is important to individuals, as well as private and public sector organizations to maintain, train and develop such a
workforce. As a result, CAI designed to support and improve learning is more important than ever.

Although a computer in and of itself cannot improve the learning process, research indicates that with proper design and application CAI can significantly improve learning achievement (e.g., Bangert-Drowns et al. 1985; Hall et al. 2000; Soe et al. 2000; Najjar 2001). But, what are the features of well-designed CAI? How can the capabilities of information technology be best utilized to improve the learning process? Over the years, many studies (e.g., Albertson 1986; Freeman 1985; Fuchs 1985; Kluger 1993) have investigated the effectiveness of specific instructional and/or design features in CAI. Yet, even though much has been learned, principles for designing CAI to support and improve learning are still needed.

Purpose of the Study

The purpose of this research is to investigate CAI design. CAI has the potential to implement methods of learning that cannot easily be achieved without computer technology, supporting the learner and the learning process in ways not possible in the traditional classroom or perhaps even in one-on-one human tutoring. The first goal of this dissertation is to derive an empirically-based set of principles for designing CAI that improves learning, exploiting the unique capabilities of computers as appropriate. The second goal of this dissertation is to codify a methodology for implementing those CAI design principles. In the process, a matrix is developed to evaluate the design features of CAI in light of the CAI design principles proposed.
Development of the Design Principles

The CAI design principles were derived from the research process. First, the design features of an existing, apparently effective CAI were reviewed and its instructional effectiveness was tested in a pilot case study and field study. For this purpose, a CAI tutorial designed for reading was investigated. CAI for reading was chosen because reading is a common, yet complex learning context. In addition, many CAI programs for reading exist. At the same time, the existing research and literature on learning, instruction and CAI, within and without of the domain of reading, was reviewed to develop an empirically-based, theoretical foundation for CAI design. Furthermore, the design features of other, less-effective CAI in the reading context were reviewed. Based on the knowledge gained from this process, empirically-based principles for CAI design were derived.

In addition, a web-based CAI named Agent99 Trainer was developed in compliance with some of the CAI design principles and methodology. To assert design principles and methodology are effective, a CAI design based on the principles of that methodology needs to be effective. Consequently, experiments were conducted on the learning effectiveness and usability of Agent99 Trainer.

Overview

This section provides an overview of each of the remaining chapters in this dissertation. The research conducted is reported herein, as follows:

- **Chapter 2 – Background on Learning and Instruction** discusses background literature on learning and instruction.
• Chapter 3 – Background on CAI Design discusses the background literature on CAI design. A theoretically- and empirically-based CAI Evaluation Matrix for evaluating the design of existing CAI software is also presented.

• Chapter 4 – Research Approach discusses the research approach and research methodologies used for deriving the principles and methodology for CAI design.

• Chapter 5 – A Pilot Study and Field Study on CAI: Methods, Analysis and Results describes a Pilot Study and a Field Study conducted to investigate the design features of an existing CAI and its effectiveness in improving learning. This chapter is divided into two main sections: Pilot Study and Field Study. Within the Pilot Study section, the CAI is described. The Field Study section is divided into three main subsections: research design, data analysis and results.

• Chapter 6 – CAI Design Principles and Methodology describes a set of empirically-based principles for designing CAI, as well as a design methodology implementing the design principles.

• Chapter 7 – A Case of Designing CAI: Agent99 Trainer describes the design and development of a CAI prototype as it relates to the principles and methodology set forth in Chapter 6. The Agent99 Trainer system is briefly described and testing of the effectiveness of the system, in terms of improving learning and usability, is discussed.

• Chapter 8 – Conclusions presents the research conclusions, contributions, and opportunities for future research.
CHAPTER 2 -- BACKGROUND ON LEARNING AND INSTRUCTION

To learn is to change; to instruct is to facilitate change.

In considering how to design an effective CAI to improve learning, it is important to understand the learning process. Learning is a complex mental process by which the learner gains knowledge, information, understanding or skill through inquiry, study, investigation, or instruction. There are many different types of learning processes: habit formation in motor skills, episodic memory of events, knowledge generation, learning strategies, and cognitive skills. Although some learning may occur without intention, learning and mastering knowledge and skills generally requires concerted cognitive effort by the learner (Driscoll 1994; Woolfolk 1998). In all instances, learning is a physical and or mental change that changes the learner’s behavior or ability.

This research focuses on intended and purposeful learning in which students/learners intentionally take actions and put forth cognitive effort to acquire knowledge and skills. For the purposes of this study, learning is a cognitively active process in which students work to construct meaning from their experiences, information/educational materials, prior knowledge and their own thoughts and beliefs (Newby et al. 2000). In addition, learning is a unique process for each learner (DeCorte 1995), affected by many instructional and learning factors.

While learning is the development of new knowledge, skills, or attitudes (Heinich et al. 1996), instruction is a systematic process that facilitates learning (Dick & Carey 1996). “A system is technically a set of interrelated parts, all of which work together toward a defined goal,” (Dick & Carey 1996). In viewing instruction as a system, there
are four interrelated factors to be considered: the learners, the learning objective, instructional materials and the learning environment (Roblyer et al. 1997; Dick & Carey 1996). The instructional system is depicted in Figure 1. Each of the factors is critical in the instructional design process. The goal of the instructional system is to achieve the learning objective. The instructional design, including the instructional method, techniques and technologies utilized, directly impacts the quality and quantity of learning (Newby et al. 2000; Schunk 2000; Sweller 1999), and thus directly impacts achieving the learning objective.

Figure 1: Instructional System

The learning environment consists of the instructional methods (i.e., procedures of instruction) and the instructional media (e.g., instructors, texts, computers, videos, etc.) (Heinich et al. 1996). The selection of materials and the learning environment should be governed by an analysis of the learners and the learning objective (Dick & Carey 1996; Heinich et al. 1996). Learning theory and instructional theory, as well as previous research should guide this process. Since the learning objective and materials are domain specific criteria, the nature of these factors will not be specifically addressed.
The focus of this chapter will be the interaction of learners and the instructional methods. Regarding the learner, active participation and cognitive effort will be discussed. On the subject of the instructional methods, the importance for learners of multisensory learning, expository learning, mastery learning, and immediate feedback will be discussed.

In this dissertation, the design of CAI is investigated in the context of a CAI reading tutorial for poor readers. Therefore, the issues affecting learners and instructional methods may be discussed in the context of poor readers as the learners and instructional methods for helping poor readers improve their reading skills.

Learners

In determining how to design CAI to support the learner, the first consideration is the learner and how learning occurs. Important aspects include the learner’s active participation and cognitive effort.

Active Participation

The learner is an active participant and processor in the learning process. Constructivists emphasize that the construction of knowledge requires the learner's active participation and cognitive effort (Piaget 1980; Glaser 1991; Vygotsky 1978; von Glasserfeld 1991; Phillips 1995; DeCorte 1995; Bruner 1961). Furthermore, Piaget (1980) stresses that the learner is required to be mentally and physically active in the dynamic processes of constructing knowledge. A learner cannot only receive information, but must process and make sense of it. “Instructors cannot pour in knowledge, they must draw it out,” (Hashway 1998, p. 55).
Cognitive Effort

The process of knowledge construction (learning) can be explained in terms of developing or constructing a mental model or schema and continuously refining the schema as new, pertinent information is discovered (Glaser 1991; Rumelhart 1980). Cognitive effort is required on the part of the learner to construct this schema, which represents the individual's understanding of the concept(s) or skills being learned. Information is evaluated and assimilated, and models are constructed and refined through the learner's experiences and active participation in the learning process (Rumelhart & Norman 1978; Sweller 1999).

Each individual has finite cognitive resources, in the form of working memory, available to process information (Miller 1956; Peterson & Peterson 1959). Each activity a person engages in consumes a portion of these cognitive resources and thereby reduces the resources available for simultaneous tasks. Cognitive load refers to the demand placed on limited working memory resources at any particular time, while cognitive effort refers to the active utilization of working memory resources to accomplish a mental task. Intrinsic cognitive load is the load inherent in the learning task. In contrast, extrinsic cognitive load uses cognitive resources in a manner that does not contribute to achieving the learning objective. For example, all types of distractions impose extrinsic cognitive load. As a consequence, reducing extrinsic cognitive load frees up cognitive resources for learning, while causing extrinsic cognitive load hurts learning.

Cognitive learning theory stresses the importance of the internal, mental processing of information including: acquisition, organization, construction, coding, rehearsal,
retrieval, storage, and forgetting, as well as the learner’s thought, beliefs, attitudes and values to when and how we learn and use the information learned (West et al. 1991; Roblyer et al. 1997; Schunk 2000).

Instructional Methods

In this section, the theoretical and empirical importance of multisensory learning, expository learning, mastery learning, and immediate feedback is discussed.

Multisensory Learning

As humans, we know all that we know through our senses, obtaining and processing new information through our sensory perceptions (James & Galbraith 1985). There are three primary perceptual modalities of learning: visual (learning by seeing), aural (learning by hearing), and kinesthetic (learning by doing) (Wislock 1993). Learners have unique perceptual preferences for learning, which afford learners their most effective and efficient modalities for learning (Wislock 1993). However, although learners often prefer using one perceptual modality as their primary channel of learning, processing and assimilating information from multiple perceptual modalities is thought to strengthen the development of their mental models.

In addition, research has shown that participants may be able to process more information in working memory when it is presented in a well-designed multiperceptual format (Miller 1956; Sweller 1999). For example, the integration of an audio explanation of an on-screen illustration can engage the aural and visual perceptions simultaneously, apparently expanding the capacity of working memory over its ability to process visual or audio information alone (Sweller 1999). In contrast, a multisensory instructional
approach is preferable to address the perceptual needs of all learners (Wislock 1993) and to facilitate effective learning by supporting schema development (Sweller 1999).

CAI can be designed to deliver multimedia instruction, helping poor readers learn to read by providing a multisensory approach that supports their perceptual preferences, allows them to process more information, and facilitates the development of their mental models for reading by engaging all of the learners’ senses. Furthermore, there is limited evidence that the use of instructional multimedia to engage and focus the learners’ attention may be particularly beneficial in helping poor readers with comprehension (Najjar 2001).

Expository Learning

Selecting an instructional method is an instrumental decision in teaching reading because the instruction method directly affects a learner's educational progress by supporting and facilitating learning or hindering it (Berliner & Rosenshine 1977; Cronbach & Snow 1977; Newby et al. 2000; Schunk 2000). The organization of the material and modality of presentation affect the learner's ability to understand and assimilate what is being taught. An instructional method should focus on helping the learner develop a mental schema (Rumelhart 1980; Sweller 1999). Since low ability learners have difficulty adapting to their learning environment, the instructional design needs to conform to their specific learning needs (Calfee & Drum 1986; Kleiman 1982).

Expository learning approaches prove to be more effective and successful learning strategies for low ability learners than discovery learning approaches (Calfee & Drum 1986). An expository learning instructional approach starts with an organized, systematic
presentation of the knowledge rules the learner needs to acquire and apply, then uses examples to allow the learner to practice applying these rules to support the development and refinement of their mental model (Marakas 1995; Schunk 2000). In contrast, a discovery learning approach starts with examples and is designed to make the learner “discover” or induce the knowledge rules as a process of their own individual search (Marakas 1995; Bruner 1961). However, low ability learners cannot construct the general rules from examples; they need explicit instructional guidance (Calfee & Drum 1986; Kleiman 1982).

Consequently, poor readers require an expository learning approach to help them learn to read. Phonics instruction is expository because it systematically teaches students about the relationships between letters and the sounds they represent (Barr et al. 1983; Flesch 1981; Jorm & Share 1983). Strong evidence exists for the inclusion of formal phonics instruction in any reading program, especially those working with poor readers (Barr et al. 1983; Calfee & Drum 1986; Carroll 1976). Thus to improve their reading skills, poor readers need to receive formal, systematic phonics instruction (Flesch 1981; Lyon 1998).

Mastery Learning

Mastery learning refers to an instructional approach in which the learner is required to "master" the material to some designated criterion level (generally 80 to 100 percent) before progressing to more advanced material (Slavin 1987; Guskey 1997). The mastery learning approach dictates a highly structured, bottom-up, expository learning curriculum (Guskey 1997; Slavin 1987) that integrates well with systematic phonics instruction. In
theory, mastery learning ensures that learners gain the prerequisite skills and knowledge needed from current studies and lessons to achieve future learning objectives (Guskey 1997). The theoretical premise is that if students master each of the required pieces of prerequisite knowledge, they will have the tools to master more advanced concepts supported by the prerequisite information. On the other hand, if learners do not gain the prerequisite knowledge for future challenges, they are prone to fail because they did not develop the necessary cognitive skills and information sets to succeed. Numerous studies have shown significant positive learning effects from mastery learning (Guskey 1997). In addition, research indicates that a mastery learning curriculum may be particularly beneficial for low ability learners (Slavin 1987; Guskey 1997). However, mastery learning instituted in the traditional classroom is commonly group-based mastery learning, which has shown limited learning effects (Slavin 1987). At the group level, time spent achieving mastery for low-ability learners means less time is available for other learners to progress to additional learning objectives (Slavin 1987; Fuchs et al. 1985). This conflict makes it difficult for teachers to dedicated adequate time for poor readers to achieve mastery in the group-based setting.

Timely Feedback

Corrective feedback is a very important component in the learning process because it facilitates the learner's evaluation of their mental models (Guskey 1997; Marakas 1995; Anderson et al. 1977). The effectiveness of feedback is a function of its content, structure, and timeliness. Guskey (1997) states, "The best feedback to students is immediate, specific, and direct, and it offers explicit directions for improvement" (p.
Feedback that provides knowledge of the correctness of response with an explanatory statement has a more positive learning effect than feedback that only provides knowledge of the correct response (Hall et al. 2000; Roberts & Park 1984). To be effective, the learner must cognitively process the feedback. Immediate feedback allows learners to easily access their relevant mental model(s) and confirm or refine that model as directed by the feedback (Rumelhart & Norman 1978). If feedback is provided too late, its value to the learner diminishes significantly. If feedback is not specific, direct and explicit, it may not be as effective (Roberts & Park 1984). On the other hand, Snow (1984) found that frequent feedback with short, highly-structured instructional tasks help focus students’ attention.

Feedback should inform the learners regarding their performance while promoting the development of the learners’ mental models. The form of feedback should be informative and encourage the learner to think and process the information. The goal of feedback is to help learners test and, if necessary, revise their mental models of the learning objective. Feedback can be varied by time (delay between response and receiving feedback) and content (structure and information provided). Some possible forms of feedback content include the following:

1. **Knowledge of correctness of response (KR),** also called verification feedback, identifies if the response is correct or wrong, and may allow the learner one or more additional tries to answer correctly.

2. **Knowledge of correctness of response with hints (KRH) identifies** if the response is correct or wrong followed by hints or strategies to help the learner determine the
correct response, and may allow the learner one or more additional tries to answer correctly.

3. Knowledge of correct response (KRC) identifies the correct response

4. Knowledge of correct response with an explanation (KRE), also called elaborated feedback, identifies the correct response and provides some explanation of correct response, and/or possibly the wrong responses.

Assessment, the counterpart to feedback, is required to evaluates learner performance. Although there is an entire field of research on proper assessment techniques, this is outside of the purview of this study. Suffice it to say that assessments should assess the learners' achievement of the learning objectives in accordance with the instruction. Herein, assessment will be considered as a means to an end. The learner needs feedback on their progress. Assessment provides a basis for providing that feedback.

Generally, assessment is thought of as an external process, but assessment can be internal to the learner. For example, students can answer questions and check the correctness of their responses, resulting in KRC feedback. Or, if an explanation of the correct response is provided, students can compare their responses and evaluate their process of arriving at those responses by studying the explanations, effectuating the more effective KRE feedback.

That concludes the discussion on the background of learning and instruction. Chapter 3 focuses on the background of CAI design.
CHAPTER 3 - BACKGROUND ON CAI DESIGN

In this dissertation, CAI refers to the use of computer technology to facilitate learning, such as in tutorials, simulations, and drill-and-practice programs. Commonly, CAI may be used independently or to supplement traditional, teacher-led instruction. In both circumstances, research has shown that well-designed and implemented CAI can significantly improve student achievement (Bangert-Drowns et al. 1985; Hall et al. 2000; Najjar 2001).

CAI is an instructional system, or part thereof. Accordingly, as in instructional design, in CAI design there are four key factors: the learners, the learning objective, instructional materials, and the learning environment that consists of the instructional methods and media. This system is depicted in Figure 2. For CAI, the primary media is computer technology, but that can incorporate many media, i.e. multimedia, such as text, audio, video, illustrations, graphics, etc.

Due to its integration of instructional materials, methods and media, CAI design creates a learning environment within an instructional system. The interaction between learners, the learning environment, and the design of CAI is the focus of this chapter. One goal of this research is to examine how CAI can be designed to implement an effective learning environment that supports effective learning. The benefits of using CAI to support the learners and implement the aforementioned instructional methods will be discussed. First, using CAI to engage the active participation of learners and focus their cognitive efforts on the learning objective will be described. Then, the discussion turns to
designing CAI to utilize technology to complement and improve the advantages of multisensory learning, expository learning, mastery learning, and immediate feedback.

![Diagram of the CAI Instructional System]

**Figure 2: CAI Instructional System - Designing CAI to Support Learners and Learning**

Active Participation of the Learner

To help learners learn, CAI needs to support the active cognitive participation of learners in developing their mental schemas. Research indicates that CAI can be designed
to support the learner’s active participation in several ways that result in significant
positive learning effects, including the following:

- cognitively engaging the learner with an interactive multimedia user interface,
- encouraging the learner to actively process information with frequent
  interactive activities, questions and feedback,
- delivering self-paced, individualized instruction (Bloom 1997; Newby et al.
  2000),
- providing a novel approach to learning (Najjar 2001),
- focusing the learner’s attention on relevant information, and
- reducing possible distractions (Sweller 1999).

These last two items relate directly to issues of cognitive load, which are addressed in the
next section.

Issues of Cognitive Load

Since each individual has finite cognitive resources, the goal of CAI design should be to focus the learners’ attentions and cognitive efforts on the learning task, while
minimizing distractions that cause extrinsic cognitive load. The issues of active
participation and cognitive load are interdependent. Active participation requires
cognitive effort focused on learning, but if working memory is otherwise engaged by
distractions, the cognitive resources will not be available for active participation.
Furthermore, distractions come in many forms, internal and external to the learner. For
instance, noise/sound, motion, daydreaming, hunger, anxiety and internal thoughts are all
distractions if they take the learner’s attention from learning. On the other hand, some of these things, such as sound and motion, can focus attention if they are relevant to the learning objective.

Focus Attention

Research has shown that CAI can be designed to focus attention. Interactivity is one method for focusing and maintaining the learner’s attention. For example, Snow & Lohman (1984) found that the implementation of short, highly-structured instructional tasks combined with frequent feedback can help focus students' attention on the learning task. Sweller (1999) states that presentation of informational sources should be complementary, but not repetitive, in a manner that does not cause split attention or learners to process information that does not help them develop their mental models. Multimedia can also help focus attention with a synchronized integration of text, visuals, sound, and/or motion (Najjar 2001). This makes processing the information easier and the benefits of multisensory learning are accomplished, with the possibility of enabling the learner to actually process more information at one time.

Minimize distractions

Visuals and multimedia should be relevant and purposeful. On screen motion (Park & Hopkins 1993) and/or illustrations (Levie & Lentz 1982) unrelated to the learning objective can distract learners and reduce achievement.

Reduce Anxiety

Anxious students have the tendency to split their attention between the learning task and self-generated thoughts of personal inadequacies and the possibility of their
failure (Tobias 1979). CAI can help to focus student attention on the computer terminal (Freeman & Clark 1985), thereby reducing student anxiety by reducing thoughts of failure. Another aspect of CAI that can focus attention and reduce anxiety is feedback. In comparison to person-mediated feedback (Kluger & Adler 1993), computer-mediated feedback has the potential to reduce the anxiety of highly self-conscious students.

Multiple Perceptual Modalities

CAI can be designed to deliver multimedia instruction, helping learners by providing a multisensory approach that supports their perceptual preferences, allows them to process more information, and facilitates the development of their mental models engaging all of the learners' senses. Furthermore, there is limited evidence that the use of instructional multimedia to engage and focus the learners' attention may be particularly beneficial in helping low ability learners with comprehension (Naijar 2001). However, multimedia can also increase the cognitive load on the learner, so it is important to design the multimedia to focus on the learning objective and not cause extrinsic cognitive load from the media.

Expository Learning

Expository learning is the counterpart to explicit instruction. If the intention is to teach new knowledge or skills, the CAI needs to be designed to deliver explicit instruction that tells the learners the factual, structural and procedural information they need to learn. Expository learning is the more efficient and effective for learning the base knowledge than discovery learning (Calfee & Drum 1986; Kleiman 1982). The explicit
instruction should be structured in chronological order based on the logical dependencies in the learning objective. In the context of reading, a CAI tutorial can be designed to effectively deliver systematic phonics instruction to poor readers, helping them develop the phoneme awareness and phonics skills they need to learn to read at a proficient level.

Mastery Learning

A CAI tutorial implementing mastery learning principles can solve the problems of group-level mastery learning by being designed to provide individual mastery learning. The CAI is able to provide personal tutoring for each student, imposing mastery learning on an individual basis while allowing each learner to progress at their own pace. Personal tutoring and individual mastery learning should result in better achievement for learners (Guskey 1997). Teaching to mastery is important in any learning context because it promotes the learning of all knowledge and skills in a structured, cumulative progression. Prerequisite knowledge is mastered before learning/mastering more advanced concepts dependent on the knowledge is attempted. In the reading context, a CAI tutorial can be designed to help poor readers improve their reading ability by providing individualized mastery learning based on their specific learning needs, thereby ensuring that the learner develops the prerequisite mental models for phoneme-awareness and phonics skills at each level before advancing.

Feedback

Although teachers may be able to give limited, one-on-one feedback to students in the classroom, it is impossible for a teacher to instantaneously evaluate the performance
of and provide immediate feedback to a classroom full of students. Yet, timely feedback is integral to the learning process. Unlike a human teacher, CAI is capable of providing immediate, personalized feedback to each student based on each student's own performance. This is just not possible for the classroom teacher. In addition, research has shown that students prefer computer-mediated feedback to person-mediated feedback (Kluger & Adler 1993). In fact, person-mediated feedback may actually debilitate the learning of students with low self-esteem or high self-consciousness (Kluger & Adler 1993). In contrast, frequent feedback with short, highly-structured instructional tasks helps focus students' attention (Snow & Lohman 1984). Therefore, a well-designed CAI tutorial has the potential to benefit the learning process for all learners by providing timely and individualized, directed feedback to each learner.

Personalized

One form of personalization is inserting the learner's name into one or more CAI components, such as: directions, instruction, activities or feedback. Another form of personalization is to customize the instruction, practice, and feedback presented by the CAI to the specific needs of a learner. The first form simply inserts the learner's name in the blank; the latter is accomplished by assessing the learner before and during the CAI use. Research has shown positive learning effects from both forms of personalization. Even rudimentary personalization of feedback in CAI has been shown to positively affect learning outcomes (Albertson 1986).
CAI Evaluation Matrix

Although many popular programs exist which are supposed to help children improve their reading skills, none of the programs reviewed by the researcher provided explicit reading instruction. Most of these programs provide some form of reading practice for students, but the students must already possess reading skills because the programs do not teach the mechanics of reading. They do not explicitly teach the sounds of letters or how to decode words. Generally, the programs reviewed provide immediate KR feedback, without providing more meaningful feedback with other corrective and/or explanatory qualities. In summary, the popular reading programs reviewed are much like automated flash cards, with some multimedia bells and whistles added for entertainment. Furthermore, the use of multimedia is often distracting from the learning objective, rather than focusing the learners attention. The features of six of the reviewed programs are displayed in the evaluation matrix in Figure 3.
### CAI Reading Programs

<table>
<thead>
<tr>
<th>CAI Design Features</th>
<th>LBAL</th>
<th>Reader Rabbit</th>
<th>Read Write &amp; Type</th>
<th>Kid Phonics 1</th>
<th>Kid Phonics 2</th>
<th>Reading Blaster</th>
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<tbody>
<tr>
<td>Learner Participation</td>
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<tr>
<td>interactive</td>
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<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td>frequently challenged to</td>
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<td>apply test mental model</td>
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<td>multimedia</td>
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<td>Instruction</td>
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<td>explicit</td>
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<td>sequential</td>
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<td>cumulative</td>
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<td>multi-perceptual</td>
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<td>Practice</td>
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<td># different activities</td>
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<td>multi-perceptual</td>
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<td>Feedback</td>
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<tr>
<td>immediate</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>multi-levels (increasing information provided)</td>
<td>x</td>
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<tr>
<td># of tries</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<tr>
<td>KR</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td>x</td>
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<tr>
<td>KR with hints</td>
<td>x</td>
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<td>KRC</td>
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<td>KRE</td>
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<td>specific</td>
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<td>personalized to error</td>
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<td>Mastery learning</td>
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<td>imposed</td>
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<td>recommended</td>
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<td>supported</td>
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<tr>
<td>Minimize Cognitive Load</td>
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<tr>
<td>multimedia focus on learning objective distractors</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
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<tr>
<td>split attention</td>
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<tr>
<td>Assessment</td>
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<tr>
<td>Pre-assessment</td>
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<tr>
<td>Frequent</td>
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<tr>
<td>within lesson</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td>after lesson (review)</td>
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<td>Record Progress</td>
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<td>current lesson</td>
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<td>learning objective</td>
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<td>Learner Control</td>
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<td>review instruction</td>
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<td>repeat practice</td>
<td>x</td>
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<td>instructional sequence</td>
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<tr>
<td>order of practice activities</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Administrative Controls</td>
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<td>assigned lessons</td>
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<tr>
<td>assigned practice activities</td>
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<tr>
<td>testing &amp; review schedules</td>
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<td>Usability</td>
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<td>case of use learnability:</td>
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<tr>
<td>ease of learning how to use</td>
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<tr>
<td>Personal Tutor</td>
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<tr>
<td>individualized lesson plan review testing based on assessment</td>
<td>x</td>
<td>x</td>
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</tr>
</tbody>
</table>

Figure 3: Evaluation Matrix for CAI Features
CHAPTER 4 – RESEARCH APPROACH

"The research process can be viewed as a series of interlocking choices, in which we try simultaneously to maximize several conflicting desiderata." (McGrath 1981, p. 69)

This chapter describes the research approach used to derive the CAI design principles and methodology put forth herein. This research was guided by the belief that no one correct approach exists to conducting IS research. Each research methodology has inherent strengths and weaknesses.

The goal of the research process is to investigate and answer research questions. In accomplishing that goal, the research process is a series of judgment calls on the part of the researcher. McGrath (1982) explains that all research evidence entails three primary decision points: Actors (some population) with Behaviors (doing something) in Context (some setting). The “perfect” research methodology would maximize three competing objectives: (A) generalizability to populations, (B) precision in measurement of behaviors/variables being studied, and (C) realism of the context in which the actors behaviors are being measured. However, it is impossible to maximize all of these equally important goals simultaneously with one research methodology. The three-horned dilemma is that the research strategy necessary to maximize any one of the three objectives (generalizability, precision or realism) necessarily reduces the other two. Therefore, McGrath (1982) states, “There is no way – in principle – to maximize all three conflicting desiderata of the research strategy domain.” All research methodologies are flawed (McGrath et al. 1982), and the implementation of any research approach involves trade-offs.
Triangulation

To counteract the shortcomings of using a single research methodology, the use of a multimethodological approach for IS research is advocated (Nunamaker et al. 1990). Triangulation of multiple methodologies can provide a complementary approach that integrates the strengths of multiple research approaches, while simultaneously mitigating the weaknesses.

![Diagram of research methodologies](image)

**Figure 4: Framework for a Multimethodological Approach to IS Research (Nunamaker 1992)**

Selecting Methodologies

The Nunamaker (1990) multimethodological framework consists of four research strategies: theory building, systems development, observation and experimentation. This framework is depicted in Figure 4. In this framework, each of the strategies interacts with the others, with theory building in the central role. All of these strategies were applied in this dissertation. As in the framework, each of the research methodologies was selected
with the overall objective of building theory by deriving principles and methodology for CAI design.

Table 1: Multimethodological Research Approach of this Study

<table>
<thead>
<tr>
<th>Research Strategy</th>
<th>Research Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory building</td>
<td>Principles and Methodology for CAI Design</td>
</tr>
<tr>
<td></td>
<td>CAI design evaluation matrix</td>
</tr>
<tr>
<td>Observation</td>
<td>Review of design of existing CAI systems</td>
</tr>
<tr>
<td></td>
<td>Review previous research</td>
</tr>
<tr>
<td></td>
<td>Pilot case study and Field study</td>
</tr>
<tr>
<td>Systems development</td>
<td>Develop CAI Prototype – Agent99 Trainer</td>
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<td></td>
<td>Usability Tests on Agent99</td>
</tr>
<tr>
<td>Experimentation</td>
<td>Field experiments of Agent99 Trainer</td>
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</tbody>
</table>

Selected Approach

As aforementioned, the selected research approach for this dissertation consisted of multiple methodologies. These included review, case study, field study, developing CAI design principles and methodology, developing a matrix to evaluate CAI design, prototype development and field experiments. Here is a brief description of each.

Review

The first methodology selected was review. In this dissertation, review refers to the observation and examination of the features of existing systems and existing research and literature. This study began with the identification of an existing CAI that appeared to be significantly improving learning over other methods. The aspects of the design and functionality of an existing CAI were reviewed, including interface design, instruction, practice activities, feedback, interactivity with the learner, learner control, administrative
controls, multimedia, assessments, and other features. This was accomplished by the researcher using the CAI in the roles of student and administrator; completing training to administer the CAI to students; reviewing the CAI instruction manuals and materials; and interviewing experts, users and the creators of the CAI. Educators and experts in the domain were interviewed to reveal the effective and unique features of the CAI that helped students learn. The goal of this review was to identify the features critical to supporting learning.

The review methodology was also used to review the design features of other, less effective CAI within the same learning context (domain) and compare those features to the design of the effective CAI. Similarities and differences were observed and examined, in light of the existing research. The researcher used each of the CAI to observe how the programs worked. In using each CAI, the researcher made observations of the design features present and their strengths and weaknesses.

Concurrently, a review of relevant research literature was undertaken in disciplines including system analysis and design, cognitive psychology, instructional design, educational psychology, interface design, learning theory, instructional theory, and CAI. In addition, since the context of the existing CAI was reading instruction, research on teaching and learning reading was also reviewed.

This review was strongly influenced by the review of the design of the existing CAI system. The goal of this review was to develop theoretical explanations for the apparent instructional effectiveness of the CAI by identifying empirical evidence for the
critical design features, as well as theoretical explanations of their importance to learning. The findings of this review are discussed in Chapter 2 and Chapter 3.

Case Study and Field Study

The case study methodology is preferred for investigating how and why questions when the researcher has little or no control of the actors or context (Yin 1994). The strength of case studies is the realism of the context (Yin 1994; McGrath et al. 1982). This methodology was selected for the pilot study of the CAI reading tutorial, due to the constraints on the researcher and the focus on realism. Likewise, the field study methodology was selected for the follow-up study to the pilot. The field study integrated case study and quasi-experimental components. Both the pilot study and field study were conducted to investigate and substantiate the effectiveness of the design features of the existing CAI. The research design and procedural specifics for the pilot study and field study are detailed in Chapter 5.

Principles and Methodology

Based on the findings from the review of prior research, the review of the design characteristics of different CAI programs, the case study, and the field study, a set of CAI design principles were logically derived. In terms of the three-horned dilemma, theory building maximizes generalizability (McGrath 1982). The objective of the CAI design principles is to contribute to the design of CAI that supports the learners in their learning objective. In addition, the CAI design principles are integrated into a methodology for designing CAI that supports learning. The principles and methodology are described in
Chapter 6. In Chapter 7, a case of applying the principles and methodology to designing a CAI prototype is presented.

CAI Evaluation Matrix

To provide a systematic method for comparing the design features of a CAI, an evaluation matrix was developed. The CAI design features in the matrix are based on the CAI design principles. The graphic display of the matrix is an excellent and revealing evaluation tool. The matrix form supports direct comparison of CAI based on the design features, and it may bring to light relationships between the design features and learning. In addition, the matrix can be used to evaluate the compliance of the design of a specific CAI with the design principles.

Prototyping

The results of the prototyping methodology are two-fold (Nunamaker 1992; Nunamaker et al. 1990). First, the prototype provides a proof-of-concept that demonstrates feasibility of the concepts. Second, the prototype is an artifact that can be tested and further developed. Thus, the prototyping methodology is an appropriate approach for providing a proof-of-concept of the principles and methodology resulting from the theory building. In McGrath's (1982) categorization, prototyping balances generalizability and realism. The CAI design principles and methodology developed in this dissertation were informally applied to the analysis, design and development of a prototype, web-based CAI named Agent99 Trainer. The development of the prototype is described in Chapter 7.
Field Experiments

A field experiment provides a compromise between realism and precision (McGrath 1982). Like a field study, the field experiment takes place in a "real" setting; however, the researcher has more control of the research design characteristics influencing behavior and is more obtrusive than in a field study. In IS research, field experiments provide a methodology for validating the theories underlying systems development (Nunamaker et al. 1990). Thus, a series of field experiments were conducted to test the training effectiveness and usability of the prototype CAI. In addition to validating theory, experimental results can be used to improve systems and the systems development process, as well as refine theories. The goal of these field experiments was to demonstrate the effectiveness of the CAI prototype and validate the proposed CAI design principles. The experiments are briefly described in Chapter 7.

Conclusion

This dissertation uses a multimethodological approach to IS research. The research strategies of observation, systems development, experimentation, and theory building were each utilized in appropriate methodologies. Although all research methodologies are inherently flawed, the integration of these methodologies complements the strengths of each to counter the weaknesses of each.
CHAPTER 5 – PILOT STUDY AND FIELD STUDY: METHODS, ANALYSIS AND RESULTS

The pilot study and field study were conducted to substantiate the effectiveness of the design features of a CAI reading tutorial, Larrabee's Bridge to Adult Literacy (LBAL) with empirical evidence. The LBAL CAI was chosen because it instantiates many of the proposed principles of CAI design. Furthermore, there was anecdotal evidence that the CAI reading tutorial appeared to be delivering very impressive results. Poor readers (school age to adults) completing the CAI were significantly improving their reading skills in minimal time. In one case, a high school drop out increased his reading ability from a 2nd grade level to adult level after completing the CAI in less than 60 hours of instruction. Learning to read truly made a difference for this learner, improving his life and his future prospects by enabling him to get a driver's license, complete a job application and get a job. The CAI appeared to be making a real difference in peoples lives; helping poor readers who had repeatedly failed finally succeed at reading. But, was the CAI truly helping poor readers learn to read? If so, how is this program different from other programs? How does it help poor readers improve their reading skills where other programs have failed? What are the critical components? What can be learned from the instructional design of this CAI reading tutorial to inform the overall design of effective CAI? These questions motivated a multimethodological investigation of the effectiveness of a CAI reading tutorial in helping poor readers improve their ability to read.
The Pilot Study

The purpose of this case study is to investigate the design of CAI by reviewing an existing CAI and investigating its effectiveness at improving learning. Due to the circumstances of the field investigation, this study was conducted as a pretest, posttest case study supported by qualitative data. A CAI reading tutorial for poor readers was selected as the sample to be studied. The research question was to determine if the design of the CAI improved learning. Specifically, did the CAI reading tutorial significantly improve the reading ability of poor readers who completed the tutorial?

The study was conducted at a Title I elementary school in a large city in the Southwest. (A Title I school serves a high concentration of students living in poverty, and as a result, receives funds to provide special educational services for low-achieving and at-risk students.) The 13 participating students were fourth and fifth grade students. The students had poor reading ability as determined by the assessment of their homeroom teacher. Their teachers referred the participating students to the reading lab for help with their reading skills. Participants attended the lab up to 5 days a week, where they used the LBAL program 30 to 60 minutes per day.

All participants were pretested and posttested with the Degrees of Reading Power exam (DRP). The DRP exam is a standardized, criterion-referenced test that measures reading comprehension. Two equivalent DRP forms were administered as pretest and posttest. The participants all tested below average when pretested on the DRP. Eleven of the thirteen participants pretested at the first grade equivalent reading level. Nine of the participants scored in the first percentile, meaning that they performed better than less
than one percent of the students in their grade level. Eight of the thirteen participants had not yet completed the LBAL CAI program at the time of posttesting.

The following hypothesis was investigated:

H1: Participant posttest scores on the DRP exam will be significantly greater than their pretest scores on the DRP exam.

In addition to DRP testing, the research question regarding the effectiveness of the design of the LBAL CAI program for improving learning was investigated. Qualitative methods were used to gain an understanding of the participants' improvements in reading ability. Student participants were individually interviewed regarding their perceptions of the LBAL program and their reading skills. The participant interview included nine objective items (rated on a Likert scale of 1 to 5, with 1 representing Strongly Disagree and 5 representing Strongly Agree) relating to preferences and perceptions on reading, writing and the program. The homeroom teachers were asked to complete a questionnaire regarding their observations regarding the participants' reading abilities and improvements observed in the classroom, as well as their impressions of the LBAL reading program. The reading specialist teaching the CAI tutorial lab was also interviewed regarding her observations of the individual student's activities and performance in the reading lab.

The CAI Program: Larrabee's Bridge to Adult Literacy

LBAL is a CAI phonics reading tutorial directed at learners from fourth grade through adult who are poor or non-readers. Because LBAL is CAI, it can provide personalized, self-paced instruction to many students simultaneously, acting like a private
tutor for each. The program is designed to be used five hours per week on a frequent and consistent schedule.

Phonics instruction is delivered via video-stream recordings of "Professor Larrabee" teaching each lesson, tasking students and providing feedback for each educational activity. LBAL provides immediate, detailed feedback to the learner as they complete each question in each exercise in each lesson. The program provides feedback for each answer as it is given. Correct answers receive an immediate, randomly selected, positive affirmation from Professor Larrabee, such as, "Super!" or "That's correct." If an answer is incorrect, Professor Larrabee provides directed feedback designed to assist the learner and gives the learner another opportunity to determine the correct answer. Thus, timely feedback is continuously provided to the learner throughout the tutorial. The program imposes 100% mastery of each exercise. Students must achieve 100% correct responses for each exercise in a lesson before progressing to the next lesson. Each lesson systematically builds on the knowledge gained from previous lessons. Cumulative review tests are administered at intervals throughout the program to further ensure mastery. If learners have weak areas, the relevant lessons are reassigned to refresh and reinforce those reading skills.

The LBAL reading program incorporates interactive video stream delivery of the material, systematic phonics instruction, 100 percent mastery, and 5 different cognitive activities for each lesson. In addition, the program is supplemented by teacher interaction with students that stresses reading fluency, inflection and comprehension. Thus, students receive formal phonics instruction to improve their decoding skills, as well as instruction
to improve their reading comprehension skills; the two components required for being a good reader.

The Lessons

With the LBAL program, each student completes a pre-assessment test and based on the individual learner's pre-existing knowledge, the program provides a personalized plan of study. The program focuses on each particular student's reading weaknesses and guides them through the needed lessons and related exercises; thereby addressing the specific needs of the learner. The learner controls the pace of the reading instruction and their progress within the current lesson.

Specifically, the reading tutorial consists of 47 possible lessons, which teach the learner phonics skills. Each lesson begins with an introduction, followed by five or six multisensory exercises. Through video streaming technology, Professor Larrabee presents the instruction for the lesson. In general, the introduction teaches the name and sound of a letter(s) or phoneme, the production of the sound, (i.e., how to physically create the sound), how to write the letter(s) involved, and other pronunciation instructions, tips or memory aids for the lesson. The learning exercises provide practice and experience with the reading skills taught in the introduction in multiperceptual modalities to help the learner construct an accurate mental model for associating the visual graphemes (letters) to the aural phonemes (sounds) required for reading. The different exercises engage all of the perceptual modalities of the learner, while the interactivity of the CAI helps to encourage and maintain the active participation of the learner and provides directed and timely feedback important to learning.
Pilot Study Results

The purpose of this case study was to investigate whether using a CAI tutorial improved learning. The context was a CAI reading tutorial so the study investigated if the CAI helped poor readers improve their reading ability. Several sources of data were collected. The findings presented below for DRP exam scores, teacher interviews, the reading specialist interview and student interviews support both hypotheses.

DRP Scores

DRP raw scores are converted to standardized DRP instructional scores ("DRP Handbook", 1995). These scores can than be converted to National Percentile Ranks (PRs) and Normal Curve Equivalents (NCEs). Paired samples statistics were run on the DRP instructional scores and the NCEs. The results are summarized in Table 2. The improvement in instructional DRP scores between pretest scores (20.61) and posttest scores (34.58) averaged 14.23. This statistically significant improvement in the students' DRP instructional score indicates that the students did improve their reading comprehension. Thus the hypothesis that "participant posttest scores on the DRP exam will be significantly greater than their pretest scores on the DRP exam" is supported (p<.001).

NCEs are normalized standard scores of the PRs. NCEs represent students' performance relative to other students in the same grade. Unlike PRs, NCEs have been statistically transformed to create an equal-interval scale, so they can be statistically analyzed (Harris & Sipay 1985). The mean NCEs for the thirteen participants significantly increased from 5.92 to 23.31, (p<.001). The significantly positive change
observed in the participants NCEs indicates that the students significantly improved their reading comprehension standing relative to other students at their particular grade level. Thus, the participating students moved up in the class rankings, indicating that they improved their reading comprehension a significantly greater amount than expected solely from maturation.

Teacher Interview

Six fourth and fifth grade teachers referred student to participate in the LBAL program. Four of these six teachers completed a written questionnaire/interview. The teachers were asked whether they observed improvement(s) in the students referred to the computer reading lab. They were further asked to provide student-specific observations. All comments were positive, and most were very enthusiastic. In response to the question, "Have you seen improvement(s) in the students you have referred to the computer reading lab?" one teacher exclaimed in writing, "Yes!!!!" Another exclaimed, "Yes, all of my (participating) students' reading has increased 2 1/2 to 3 years of reading in less than a year!!" The teachers' student-specific observations reported the following: better oral reading and word attack skills, increased spelling accuracy, improved writing, increased vocabulary, and improved self-confidence. One teacher wrote, "(Student's) reading has increased from 1st to 4th grade. He is in 4th grade now and is going to 5th. His vocabulary has increased. His spelling has improved significantly!" All of these improvements were not observed in every student, but the teachers' responses reveal that they did observe noticeable improvement in each of their participating students that the teachers attributed to the LBAL program. In the words of one teacher, "All the kids that
participated in the program demonstrated improvement in their willingness to read aloud and their confidence."

Table 2: Results of Paired Sample t-Test on DRP Instructional Scores and NCEs

<table>
<thead>
<tr>
<th>DRP Scores</th>
<th>DRP Pretest</th>
<th>DRP Posttest</th>
<th>Pretest-Posttest Difference Scores*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DRP Instructional Scores</strong></td>
<td>Mean 20.61</td>
<td>Mean 34.85</td>
<td>Mean 14.23</td>
</tr>
<tr>
<td>SD 8.38</td>
<td>SD 8.54</td>
<td>SD 8.83</td>
<td></td>
</tr>
<tr>
<td>N 13</td>
<td>N 13</td>
<td>p &lt; .001</td>
<td></td>
</tr>
<tr>
<td><strong>DRP NCEs -- standardized rankings</strong></td>
<td>Mean 5.92</td>
<td>Mean 23.31</td>
<td>Mean 17.38</td>
</tr>
<tr>
<td>SD 8.92</td>
<td>SD 12.36</td>
<td>SD 9.17</td>
<td></td>
</tr>
<tr>
<td>N 13</td>
<td>N 13</td>
<td>p &lt; .001</td>
<td></td>
</tr>
</tbody>
</table>

**Differences represent increases in scores from pretest to posttest.

Interview with the Reading Specialist

Throughout the duration of the study, the reading specialist recorded field notes on observations of the students in the computer reading lab. At the end of the school year, the researcher interviewed the reading specialist regarding her observations and notes. Each student was discussed. The reading specialist reported that she observed improvements in all of the students that she believed were attributable to their participation in the LBAL program. In addition, her observations included rich information regarding the students' performance, attitudes, abilities, behaviors and accomplishments. Some of these observations are reported below in the discussion of the student interview qualitative items.

Student Interviews

Eleven of the thirteen student participants were interviewed at the end of the school year. Eight of the eleven interviewed had not completed the program at the time of interview. Two participants were unavailable for interview because they moved before
the interviews were conducted. The interview consisted of both objective and subjective items. One-on-one interviews were conducted with each student to ensure that the students could understand the questions and thus mitigate errors that might result from poor reading comprehension skills, writing aversions or misunderstanding of how to respond to the items. The researcher explained to each student that the purpose of the interview was to obtain the student's opinions regarding reading and the CAI program. To mitigate outside influence in their answers, the students were assured that their answers were confidential and would not be shared with teachers. The researcher stressed that she wanted the students' true opinions in an attempt to reduce the potential for "pleasing" bias. The Likert scale was verbally reviewed and a printed copy of the scale was given to the student for reference. The researcher read each question aloud and recorded the student's responses. Students were encouraged to ask questions during the interview process if any items were confusing.

Student interview: Objective items

The student interview questionnaire included nine objective items, rated on a five-point Likert scale: 1 = Strongly Disagree, 2 = Agree, 3 = Neither Agree or Disagree, 4 = Disagree, and 5 = Strongly Agree. A five-point Likert scale was chosen because it has been shown to be more appropriate for the elementary grade age group than a larger scale. Refer to Table 2 for the items, response frequencies and mean responses.

Items 1, 2, 5, and 6 are general questions about the learners' attitudes toward reading and related activities. Items 3, 4, 7 and 9 investigate the participants' attitudes and perceptions regarding the LBAL program. Specifically, items 7 through 9 were designed
to discover students' perceptions about whether participating in the LBAL program improved their reading skills, as well as their perceptions about their own reading ability. Items 6 and 8 were stated in the negative to provide a check for responses and understanding of the scale. Responses about reading attitudes and the LBAL program were expected to be positive (above a 3 average).

As shown in Table 2, all but one of the positively stated items averaged above a 4, with item 1 (I like to read.) averaging 3.727. These ratings indicate that the participants liked to read and liked to write at the end of the school year. Of particular interest are the responses to items 7 and 9. The average responses for items 7 and 9 were 4.455 and 4.400, respectively. These high positive responses strongly indicate that the participants believe that the LBAL program helped them become better readers and increased their enjoyment of reading. These responses agree with the findings from the DRP test scores and the qualitative interview data reported below, providing support for the second hypothesis that completing the LBAL program helps poor readers improve their reading ability.
Table 2. Student Responses on Objective Interview Items

<table>
<thead>
<tr>
<th>Item</th>
<th>Response Frequency*</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I like to read.</td>
<td>2 2 4 3</td>
<td>3.727</td>
</tr>
<tr>
<td>2. I like to go to the computer reading lab.</td>
<td>2 6 3</td>
<td>4.091</td>
</tr>
<tr>
<td>3. I like to use the Larrabee program.</td>
<td>1 5 5</td>
<td>4.364</td>
</tr>
<tr>
<td>4. The Larrabee program is fun.</td>
<td>1 5 5</td>
<td>4.364</td>
</tr>
<tr>
<td>5. I like to write.</td>
<td>1 1 5 4</td>
<td>4.091</td>
</tr>
<tr>
<td>6. I do not like to read.</td>
<td>6 3 1 1</td>
<td>1.818</td>
</tr>
<tr>
<td>7. The Larrabee program has helped me become a better reader.</td>
<td>1 3 7</td>
<td>4.455</td>
</tr>
<tr>
<td>8. I do not read as well (or the same) as I always have.</td>
<td>2 2 2 1</td>
<td>2.286</td>
</tr>
<tr>
<td>9. I like to read more now than I liked to read before I started the</td>
<td>2 2 6</td>
<td>4.4</td>
</tr>
<tr>
<td>Larrabee program.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Likert scale: 1=Strongly Disagree, 2=Disagree, 3=Neither Agree or Disagree, 4=Agree, 5=Strongly Agree

Student interview: Qualitative items

During the interview, students were asked the six subjective items. The following presents each item, the intended purpose of each item, and the participant responses.

1. Why did you start the Larrabee program?

The first question, "Why did you start the Larrabee program?" was asked to determine if the students self-identified as poor readers, in agreement with their teachers' assessments. They did. Nine of eleven interviewees blatantly stated that they needed help with reading. Responses included comments such as, "Because I didn't know how to read," and "I needed help on reading and writing." The reading specialist also confirmed their status as poor readers.

The remaining interview questions were directed at developing an overall picture of what the participants thought about the Larrabee program, including whether or not they believed that the program has helped them improve as readers.
2. What makes the Larrabee program FUN or NOT FUN?

Participants revealed that the Larrabee program was fun at times, but not fun at others times. Several characteristics of the Larrabee program were identified as making the program fun. Some students liked using the computers. One student noted, "It's just fun using computers." This supports that the CAI is a novel approach. More prevalent, however, was the fact that the students felt the program helped them. The students experienced success with reading and received positive feedback. The following are representative statements by participants.

- "It helps me. I like it."
- "It's fun because when you get words right, he (Professor Larrabee) says things like, "Great job!" and "Nice job."
- "(I'm) happy when you get to a different grade level of reading and/or move to a new lesson."

In addition, the reading specialist reported that the students expressed pleasure and excitement when they answered questions correctly and completed lessons. Students might smile or raise their arms in victory.

However, the program was not always fun. A few students commented that the program was not fun when they answered incorrectly or the lessons were "too hard." This agrees with observations of the reading specialist. The reading specialist reported that at times some participants got very frustrated with the program. A couple of students would get very mad and either throw their headsets, yell at Professor Larrabee, or even punch him on the computer screen. Yet, despite the frustrations, these students thought
there were fun aspects of the program. When interviewed, the student who used to punch
the screen strongly agreed with the statement, "The Larrabee program is fun."

3. How has the Larrabee program helped you become a better reader?

Participating students identified the phonics instruction (the sounds of letters and
how to sound out words) and personalized feedback as components of the program that
helped them become better readers. Student comments included:

- "He and Ms. ______ (the reading specialist) told me to sound it out. It taught me
  the different sounds for the letters and the sounds I did not know. Taught me
  how to sound out the words."

- "By, if I get words wrong he'll say them again very slow, if I get them wrong
  again he'll write them down and come back to them."

- "The computer helped me. It gives me another chance if I miss words, tells me
  if I still do not get it right and (then) I write it on a board."

All but one student agreed or strongly agreed that the Larrabee program helped
them become better readers. Interestingly, the student who disagreed showed marked
improvement in testing of reading comprehension even though she had not completed the
program. Her DRP instructional score raised thirty-six (36) points out of 100, and she
moved from the first to the 16th percentile in comparison to the reading comprehension
of students at her grade level. This same student later stated that she would tell a friend,
"I think it's (the Larrabee program) fun and it teaches me something." Thus, although she
may not have considered herself to be a better reader, she did perceive that she was
learning by using the program.
4. Name the 3 things you like/dislike most about the Larrabee program.

These two questions were asked to prompt students to identify specific features of the program that they liked and disliked. This information may provide insight into useful features, as well as ways to improve CAI tutorials. Understandably, students did not like specific lessons or exercises that were very difficult for them, took a long time to complete and caused frustration. They did not like being wrong. The other primary complaint was computer problems. Students did not like it when computers locked up during lessons or were broken and not available for them to use. Although computer problems are independent of the CAI program content, technical problems do effect the attitude of the participants.

In discussing what they liked most about the Larrabee program, participants listed both specific features of the program and benefits from the program. Of course, individual students named different features, but the participants as a group included every learning exercise in the list of features liked most. There was no consensus regarding which exercises were preferred. This makes sense since the different exercises engage different perceptual modalities and different learners have different preferred learning modes. Benefits identified as "things you like most about the Larrabee program" included characteristics such as: it was fun, it helped me read better and it taught me phonics rules. As one participant stated, one of the things she liked most was, "I now know rules that help me sound out words."
5. What would you tell a friend about the Larrabee program?

This question was designed to reveal how the student might describe the Larrabee program to peers. When asked what they would tell a friend about the program, all the students had positive remarks that indicated they would recommend the program to peers. "(I would tell a friend) that they should go to the Larrabee program if they need help on their reading," said one student. Many other participants made statements similar to, "It's fun. You learn how to read."

6. Overall, what do you think about the Larrabee program?

The purpose of this question was to capture participant opinions about the Larrabee program as a whole. It also provided a catchall for any general opinions or comments. The interview process revealed that this was probably a poorly worded question for the fourth and fifth grade audience. A number of students did not understand the question because they were unfamiliar with the word "overall." Other students simply had nothing to add. The responses that were received were very similar to those given for the previous question, "What would you tell a friend about the Larrabee program?" However one particular comment merits mention. One student stated, "It (the LBAL program) should be discovered all over the U.S. and taken by people that can barely read."

Obviously, this student believed that the LBAL program is effective in helping poor readers learn to read.

In conclusion, the student interviews indicate that the poor readers using LBAL perceived that the program helped them improve their ability to read. This finding concurs with the improvement in the DRP scores and the observations reported by the
teachers and the reading specialist. Thus, the triangulation of these different data sources supports both hypotheses: 1) the participants significantly improved their reading ability, and 2) completing the LBAL program helped the poor readers make that improvement. Therefore, it follows that completing a CAI reading tutorial helped poor readers significantly improve their reading ability.

Discussion

The 4th and 5th grade poor readers who completed this integrative phonics-based computerized reading tutorial improved their reading comprehension. The quantitative and qualitative findings support this conclusion. Test scores, student interviews, teacher interviews and the interview with the reading specialist all indicate that the Larrabee program helped the poor readers who participated in the program improve their reading skills, including reading comprehension, oral reading, and spelling. Students experienced frustrations with the program, as would be expected in any complex learning process. However, this would not have occurred if they were not actively engaged and personally vested in the learning process. And, the participants were excited about their successes. They were becoming better readers and they knew it. They were proud of their accomplishments and this was reflected in improved performance, confidence and attitudes in the classroom. Students who previously refused to read aloud in class began volunteering. Others proudly told classmates, teachers and parents about their progress. Three participants made a sincere and heartfelt speech at their fifth grade graduation to publicly thank the Larrabee's program for teaching them to read. Parents also observed
improvements at home. Some parents reported how excited they were to see their children reading on their own for the very first time.

There are several factors contributing to this result. First, students who are poor readers generally have poor phonics skills. The tutorial’s systematic and comprehensive approach to phonics allows each student to go at their own pace, focusing on learning the phonics rules that cause that student problems. Each lesson contains at least five types of exercises to test the student’s knowledge and understanding. The exercises are designed to engage different cognitive skills in multisensory perceptual modes, guiding the learner to develop a more complete mental model for the concepts in each lesson. In addition, the tutorial requires 100 percent mastery of each lesson, thereby ensuring that the student fully understands each phonics concept before proceeding to succeeding lessons which will incorporate skills from the preceding lessons. Finally, the CAI reading tutorial helps students improve their reading skills because the computer can provide hours of individualized tutoring with timely directed feedback, unlimited patience and no perceived judgments of performance. The combination of these factors helps poor readers learn to read.

The Field Study

This field study was a follow-up study to the Pilot study described above. The purpose of the study was to investigate the design and effectiveness of a CAI reading tutorial and the CAI design elements that make the tutorial effective.
Research Design

This combination of a quasi-experimental study and a case study was conducted at a Title I elementary school in a large city in the Southwest. This study was designed in accordance with the field study limitations and lessons learned during the pilot study. First the researcher realized that it would not be possible to implement two design features: 1) random assignment of participants or 2) a control group using an alternative computerized reading tutorial. As a result, the research design provided for alternative features. Instead of random assignment, an alternative plan was devised to back into a control group of students in the same grade, classes and school who were not attending the reading tutorial lab. The selection of the control group is described in the Control Group section below.

Participants

The participants in this study are seventy-one (71) 4th and 5th grade students at a Title I, k-6 elementary school in a large school district in the southwest. Title I schools serve a high concentration of students living in poverty, and as a result, receive funds to provide special educational services for low-achieving and at-risk students. All 4th and 5th graders at the school were asked to volunteer to participate in this study. An attempt was made to pretest (beginning of the Fall semester) and posttest (end of the subsequent Spring semester) all 4th and 5th grade students with the DRP exam. The DRP is a research measure of reading comprehension that is described in detail in the measures section. Those students who were not available to be both pre and posttested, due to absence when the tests were administered or other reasons, were necessarily excluded from the
study. In addition, participating students could not have used the tutorial prior to the start of this study. Thus, students who used the reading tutorial in prior years, including the pilot study, or during the summer program were excluded as participants in this study. However, some of the students who had previously used the CAI reading tutorial did volunteer to pilot the student interview questionnaire for the researcher.

Treatments – Independent Variables

The independent variable is the method of reading instruction. This is an active variable with two categories defined by whether or not a student uses the CAI reading tutorial during the school year (yes or no).

Assignment to Treatments

Random assignment of participants to treatments was not possible due to the nature of this field study. Understandably, teachers wanted to send students whom the teachers felt were in need of help with their reading to the reading lab. Therefore, assignment to the treatment group was determined by the student’s teacher, independent of any research measures. Since it was impossible to know at the onset who would be sent to the reading lab and who would not, assignment to the control group was determined at the end of the study. Both procedures are described below.

Treatment Group – CAI Phonics-based Reading Tutorial

The students participating in the CAI reading tutorial are students with poor reading skills, as determined by their homeroom teachers. The students that used the reading tutorial were sent to the reading lab because they were identified by their homeroom teachers as poor readers who need additional reading instruction. The teachers
determined this based on their individual methods of evaluation and their observations of classroom performance by the respective students. These methods were not standardized or controlled across the teachers. In addition, the teachers did not have knowledge of the students’ pretest DRP scores, so assignment was independent of the students’ performance on the DRP exam, as well as all other research measures. When a teacher determined that a student had poor reading skills and needed help, the teacher would recommend to the student and the student’s parents that the student attend the reading lab. Thus, the participants in the treatment group are students with below average reading ability, students who ostensibly need the treatment rather than students with a wider range of reading abilities. As a result, the findings are generalizable to the students of interest, students with reading difficulties. Since assignment to the treatment group was independent of the research measures, the method of assignment avoids a statistical regression to the mean effect (Campbell & Stanley 1966). In addition to completing pre- and post- DRP tests, the students in the treatment group completed pre- and post-treatment oral readings and extensive interviews at the end of the Spring semester.

Control Group for DRP pretest and posttest data

Since the researcher did not have control of when or which students would be assigned to use the CAI reading tutorial (treatment group), the students composing the treatment group or the control group could not be predetermined. The research plan was to determine the composition of the control group at the end of data collection, i.e. the students in the control group would be selected from students that were pre and post tested on the DRP exam, but who were not assigned to the reading tutorial during the
school year. The question thus presented was how to select the control group from these students. In answering this question, Kerlinger’s (1984) MaxMinCon principle and the methods he identifies for controlling variance were considered.

**MaxMinCon.** The purpose of research is to answer research questions. Research design enables the researcher to 1) investigate and find answers to research questions, and 2) control systematic and unsystematic variance in the process. Kerlinger’s (1984) statistical MaxMinCon principle explains that a researcher attempts to maximize the systematic variance of the experimental variables, minimize the error variance, and control for extraneous variance due to extraneous variables not of interest to the research at hand. A researcher applies the MaxMinCon principle through the research design. Following is a brief explanation of each of the components of the MaxMinCon principle.

**Max.** Systematic variance is the variance between groups due to the variables of interest. If systematic variance is too small, there will be no statistically significant difference, which results in a false negative. Thus, the researcher wants to maximize the differences between treatment groups so that any real differences between treatment groups are measurable.

**Min.** Researchers want to minimize error variance so that it does not interfere with the measurement of the systematic variance in the research variables. Error variance results from within group variance, as well as measurement error. Likewise, the researcher wants to minimize (and control or measure) extraneous variance, which also becomes part of the error term.
Con. "A researcher tries to systematically rule out variables that are possible causes of the effect other than the variable that the researcher has hypothesized to be a 'cause' (Kerlinger 1984, p.4)." These variables are extraneous variables because they are outside or extraneous to the research question. Therefore, extraneous variance is the variance between participants or between groups due to variables not being studied in the current research. Kerlinger (1986) describes five methods of controlling the systematic variance of extraneous variables. These five methods are:

1. Make the variable a constant.
2. Randomization of assigning participants to groups and/or groups to treatments.
3. Build the extraneous variable into the research design as an independent variable and measure it.
4. Match participants in the treatment groups based on extraneous variable(s).
5. Conduct covariate analysis.

Each method is briefly discussed below. Possible extraneous variables identified to control were grade level, gender, homeroom teacher, and pretreatment reading ability. Each of these variables could possibly affect the learning ability of the students, and thus affect their posttest scores. The first two of the methods to control extraneous variance were not possible to implement in the present research design due to a lack of available participants and/or the researcher's lack of control of assignment. However, the three attribute extraneous variables, grade, gender and homeroom teacher, were measured to possibly control in the study. As discussed below, matching (a design method) and covariate analysis (a statistical method) were both attempted as possible methods to
control extraneous variables. In the end, it was determined that none of these methods was applicable to the sample in this study.

1. Making a variable a constant. An attribute variable, such as gender, can be “made” a constant if all participants are the same value for the attribute, for example if all participants are female students. As Kerlinger explains, the purpose of making a variable a constant is to eliminate the variable as a variable in the research design and thus make the participants as homogeneous as possible to control extraneous variance (Kerlinger, 1986, pp. 287-288). This method is a very effective method of controlling variance because it removes it from the start, but it has the great disadvantage of impeding generalization power, and also limiting the number of available participants.

The attribute variables to be considered in this study were gender, grade level and homeroom teacher of the participants. This method could not be implemented for several reasons. First, the researcher did not control assignment of students to the treatment, so gender, grade and teacher could not be held constant. Second, there were a limited number of students in the treatment group and trying to make any of the attribute variables a constant would have further reduced the number of participants. Third, holding teacher constant would have effectively introduced a confound from the teacher’s classroom teaching method since all the students (treatment and control participants) received classroom instruction and reading is an integral part of most classroom instruction. And, finally, making the attribute variables gender, grade, and/or teacher constants was not desirable for this study because it would have severely limited the external generalizability of the results.
2. **Randomization of assigning participants to groups and groups to treatments.**

Theoretically, randomization controls for all extraneous variables because properly randomized groups are statistically equal. Randomization is the a very powerful method for controlling extraneous variance because it controls for known variables, and perhaps more importantly, it controls for variables not even suspected to exist (Campbell & Stanley 1966; Kerlinger 1986). However, true randomization can be hard to achieve, and it is often impossible, such as in field studies where researchers cannot control assignment. Consequently, researchers are often trying to approximate or come close to randomization to achieve at least some of its benefits. As stated previously, random assignment of students in this study was not possible because the researcher could not control assignment.

3. **Build the variable into the design.** Build the variable into the design simply means to measure the extraneous variable(s) as part of the research. This makes the “extraneous” variable an independent variable in the research design. Measuring the variable allows the researcher to include it in analyses and “control” for its possible effects by removing the variance in the dependent variable due to the “extraneous” variable (Kerlinger 1986). However, adding additional variables to the analysis may also reduce the power of the analysis. The students’ grades, gender, and homeroom teachers were measured so that possible effects of the variables could be controlled, but the sample size was too small to control for these variables in the analysis without significantly affecting power. However, the DRP pretest score provides a measure of
reading ability, operationalized as reading comprehension, that was controlled for with a repeated measures design.

4. **Matching.** Matching is an alternative method that may be considered when random assignment of participants is not possible. In matching, the extraneous variables are built into the research design and measured for the purpose of creating equivalent treatment groups based on the extraneous variables. The researcher matches the participants on the extraneous variables, creating pairs (in the case of two treatment groups), and then places one participant from each pair in each treatment group. This is generally accomplished before treatment, and when possible each group is then randomly assigned to one of the research treatments. When the groups cannot be randomly assigned to the treatment received, matching is not as effective a control as randomization because, whereas randomization will theoretically control for all extraneous variables (whether the researcher has identified them or not), at best, matching will control for the extraneous variables identified. If the matching (extraneous) variables are not highly related to the dependent variable, the matching will be ineffective in controlling extraneous variance. Another problem with matching is that the more extraneous variables to be matched upon, the greater the pool of potential participants required and the more likely matching will not be possible.

In this research study, matching of students in the treatment and control groups was planned and tested as a method to remove extraneous variance. Four attribute variables (grade, gender, pretest DRP score and student’s homeroom teacher) were identified as being possible variables to be used for matching to control extraneous variance and bias.
The primary concern was the between group differences of the beginning reading ability of the students and their ability to learn. Since the researcher could not control assignment to the treatment groups, the matching was attempted post data collection. An attempt was made to match students from the pool of potential control group participants, with the students in the CAI reading tutorial treatment group to create pairs. However, as is common in matching, there were not enough students to create matched groups. It was impossible to match on the DRP pretest, which was not surprising since the poorest readers were assigned to the CAI reading tutorial by their teachers, making the treatment group significantly different. A best possible matching was done based on student grade (4th or 5th), gender and pretest DRP scores, but an analysis based on the pretest scores showed that the resulting matched groups were not equivalent. Therefore, this form of matching was abandoned as a method for selecting the control group from the candidates. However, according to Kerlinger (1986) repeated measures provides a form of matching because you are matching on the same participant for the pre and post tests. In the end, a repeated measure analysis was conducted using all of the possible candidates for the control group.

Covariate analysis. Covariate analysis is a method of statistically making a variable a constant. Although it is actually an analytical technique, the choice of using covariate analysis is directly related to the decision of how to select the control group, thus it is included in this discussion of methods. In covariate analysis, the covariate selected is an interval level data variable that is suspected to represent a source of extraneous variance. Since the concern was extraneous variance due to the inequality of the initial reading
ability of the students between groups, the DRP pretest score variable was considered as a covariate to remove extraneous variance. However, when tested, covariate analysis was not appropriate because there was a significant interaction between the DRP pretest scores and the treatment. This is likely a result of the assignment method, since students were assigned to the reading tutorial treatment based on their poor reading skills, it makes sense that their DRP pretest scores would be significantly lower than the control group, resulting in a statistical interaction.

Consequently, the control group for the analysis of the DRP scores consisted of all possible candidates, i.e. all students that were pre and post tested on the DRP exam, but who were not assigned to the reading tutorial during the school year.

Measures – Dependent Variables

Many sources of data were collected. Pretest-posttest DRP scores were collected from the treatment and control groups. Interviews of students, homeroom teachers, and the CAI lab reading specialist were conducted. The description of these measures follows.

DRP Scores

The Degree of Reading Power (DRP) tests are criterion-referenced, standardized, reading comprehension examinations. Raw DRP test scores are converted to DRP Scores, which are standardized instructional scores designed to inform teachers of a student’s reading level ("DRP Handbook" 1995). The DRP scores can then be converted to National Percentile Ranks (PRs) and Normal Curve Equivalents (NCEs), if so desired.
PRs represent the rank-order standing of a student in comparison to other students in the same grade. For example, a PR of 25 means that the student scored equal to or above twenty-five percent of the other students in the norms sample for that grade. It is not statistically appropriate to mathematically manipulate PRs because they do not create an equal interval scale (Harris & Sipay 1985). Therefore, NCEs should be used to statistically compare pretest and posttest rankings. NCEs are normalized standard scores that are based on the PRs. Like PRs, NCEs represent students' performance relative to other students in the same grade. However, unlike PRs, NCEs have been statistically transformed to create an equal-interval scale, so they can be statistically analyzed (Harris & Sipay 1985). DRP NCEs have a mean of 50 and a standard deviation of 21.06 ("DRP Handbook" 1995). An change in NCEs represents a relative change in a student’s ranking compared to other students in the same grade, whereas the norm would be to remain constant.

“On DRP tests, reading comprehension is defined operationally as the ability to use the syntactic and semantic information in prose passages to complete or restore a missing section of a message correctly” ("DRP Handbook" 1995, p. 58). The multiple-choice tests require students to select the best semantically sensible response from five possible words to fill in the blanks in prose passages. The DRP tests are a proprietary literacy assessment tool provided to the educational marked by Touchstone Applied Science Associates (TASA), Inc. The DRP program is adopted by over 3400 schools, colleges and universities, nationwide, where the DRP tests are an accepted method for testing
students' reading comprehension. More specific information on TASA and the DRP program can be obtained on the TASA website at www.tasa.com.

The DRP Handbook (1995) provides an overview of the technical characteristics of the DRP tests. The DRP tests have been constructed and scientifically tested to ensure the reliability (internal-consistency, test-retest reliability, and alternate form reliability), validity (construct validity, content validity, and criterion-related validity) and test fairness (item bias and test bias) of the DRP test ("DRP Handbook" 1995). Research shows that the DRP tests have high internal-consistency reliability (Kuder-Richardson (K-R 20) reliability coefficients of .90 to .94 when different forms were tested with students of grades 2-8), high alternate-form reliability and high test-retest reliability within a one- to two-week period (K-R 20 = .95); and to be effective at detecting gains in reading comprehension over longer instructional periods (after 5 months) ("DRP Handbook" 1995, pp. 56-58).

Research also shows that the DRP test has construct validity, content validity and criterion-related validity ("DRP Handbook" 1995, pp. 58-59). First, DRP tests have construct validity because research has shown that the DRP tests solely measure reading comprehension, independent of content knowledge. This is supported by the high correlation of the readability of a DRP passage with the difficulty of DRP test items embedded in that passage (r = .95). Second, DRP tests have construct validity because there is a positive correlation between the ability of students (low, middle, high) and their performance on items based on item difficulty (easy, moderate, hard). Topics of DRP test items are randomly selected from all possible prose subject matter to mitigate content
bias and ensure content validity. Finally, the DRP tests were validated against a criterion measure, a similar reading comprehension test in which students are required to create semantically sensible responses to fill in blanks in prose, as opposed to the DRP test method of selecting the best choice to fill in the blanks. The DRP test scores were shown to be highly correlated with the criterion measure scores ($r = .90$), indicating high criterion-related validity.

In addition, the DRP test has been tested for item bias and test bias with regard to the students' ability (low, average or high-ability), ethnicity or race (African Americans, Caucasians, or Hispanics), gender, or low or high socio-economic status (SES). Research shows that each of the subgroups scored equally well on the DRP items, indicating no item bias exist ("DRP Handbook" 1995, pp. 60-61). The Rasch model fit statistics reported ranged from 1.01 to 1.04, where 1.0 indicates a perfect fit. The correlations of Rasch item difficulties between subgroups were reported as follows: African Americans and Caucasians ($r = .98$); African Americans and Hispanics ($r = .98$); Hispanics and Caucasians ($r = .96$); females and males ($r = .99$); and low- and high-SES levels ($r = .98$). Furthermore, no significant interactions between DRP test scores and race, gender or SES were reported, indicating no test bias exists either. Consequently, the research has demonstrated the reliability, validity and fairness of the DRP tests.

**Structured Student Interviews**

At the end of the school year, a structured interview was individually conducted with each of the participating students assigned to use the LABL reading tutorial by the researcher. Based on the knowledge and findings from the Pilot Study and existing
research, the structured interview was constructed to reveal the students' perceptions regarding: 1) their reading abilities, 2) the benefit of the LBAL CAI in helping them learn to read, and 3) the benefit of specific instructional components, activities and strategies incorporated in the CAI tutorial. In addition, demographic information was collected.

The student structured interview questions were piloted for clarity and comprehension by fifteen 4th and 5th grade students who previously had used the LBAL CAI. The student interview questions went through several revisions as a result of the week long piloting process.

The final structured interview questionnaire included both close-ended and open-ended questions. Most of the close-ended items consisted of statements that the students were asked to answer by choosing one of four ordered response alternatives. A few of the closed-ended items were questions with unique response alternatives consisting of three or four choices. Several of these statements served as prompts for open-ended “Why?” questions. The students were asked why they answered as they did to investigate the constructs of interest. In addition, the “why” questions provided the opportunity to check the students comprehension of the items and allowed the researcher conducting the interview to clarify any confusion.

The set of four response alternatives used for most of the closed-ended statements was chosen because it has been shown to be appropriate for the students’ age group (Wigfield & Guthrie 1995). The four response alternatives in Table 3 were borrowed from the four-point response scale of the Motivations for Reading Questionnaire (MRQ). The MRQ was designed and developed by Wigfield in a research project for the National
Reading Research Center (Wigfield & Guthrie 1995; Wigfield & McCann 1996; Wigfield 1996). Since the MRQ questionnaire was designed to be used with children in late elementary school and middle school (Wigfield 1996), the wording of the response alternatives should be age appropriate for the 4th and 5th grade participants in this study.

Table 3: 4-point Response Scale for Student Interview Questionnaire

<table>
<thead>
<tr>
<th>Please answer the questions in the following way:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>If the statement is <strong>very different from you</strong>,</td>
<td>choose 1 for <strong>Strongly Disagree.</strong></td>
</tr>
<tr>
<td>If the statement is <strong>little different from you</strong>,</td>
<td>choose 2 for <strong>Disagree.</strong></td>
</tr>
<tr>
<td>If the statement is <strong>little like you</strong>,</td>
<td>choose 3 for <strong>Agree.</strong></td>
</tr>
<tr>
<td>If the statement is <strong>a lot like you</strong>,</td>
<td>choose 4 for <strong>Strongly Agree.</strong></td>
</tr>
</tbody>
</table>

In addition to the statement and "why" questions, a number of open-ended questions were included in the structured interview. The student structured interview questionnaire is included in Appendix C.

**Oral Readings**

The students in the treatment group were recorded reading two text passages, pre and post treatment. The pre and post readings consisted of the same two passages, a short, relatively easy passage (Passage A) and a longer, more difficult passage (Passage B), both presented in Table 4. These passages were selected from offline activity worksheets in the program designed to promote reading comprehension. Passages A & B were the first/easiest and last/hardest passages, respectively, provided for the students to read aloud to their teacher, which in this case was the computer lab reading specialist. The easiest and hardest passages were selected to provide a measure of performance that could measure improvement in the poorest readers, and relatively better readers, yet provide ample room for improvements. If only the easy passage was used, then it would not measure the ability or improvement of those that could already read Passage A, or
large improvements in reading ability, post treatment. However, if only the hard passage was used, it might not measure the pre-ability of the poor readers with enough delineation, and might be too difficult to show modest improvements. Therefore, both passages were included to measure oral reading.

The readings were evaluated using the qualitative reading inventory running record (RR). The RR method is a form of miscue analysis that records the student’s miscues in reading the text, resulting in two possible measures: accuracy rate and acceptability rate. An objective measure, accuracy records every miscue, with the exception of self-corrections, by the reader in the oral reading as an error. In contrast, acceptability is a more subjective measure because it considers the meaning of the text and the understanding of the reader; oral miscues that do not change the meaning of the text are not considered errors. Each rating is a percentage computed as errors divided by total words in the text passage.

Table 4: Oral Reading Passages

<table>
<thead>
<tr>
<th>Passage A</th>
<th>Passage B</th>
</tr>
</thead>
<tbody>
<tr>
<td>pat is at bat.</td>
<td>Vitamin Supplements</td>
</tr>
<tr>
<td>pat did hit.</td>
<td>The Recommended Daily allowance was instituted over 40 years ago by the U.S. Food and Nutrition Board. This board determined the daily amount of vitamins that are necessary to prevent disease. They developed the bare minimum necessary to ward off such diseases as rickets, scurvy and blindness. What it did not account for is the amount needed to maintain maximum health rather than borderline health. The Recommended Daily allowance is too generalized and cannot be easily obtained from the food we eat today. Professionally speaking, many nutritionist recommend vitamin supplements be used daily.</td>
</tr>
<tr>
<td>can nick tag pat?</td>
<td></td>
</tr>
<tr>
<td>nick can tag pat.</td>
<td></td>
</tr>
<tr>
<td>pat is sad.</td>
<td></td>
</tr>
</tbody>
</table>
Hypotheses

The following hypotheses were investigated. The hypotheses are organized according to the measures to which they relate.

**DRP**

**H1:** Students using the LABL CAI reading tutorial will achieve DRP posttest scores that are significantly greater than their DRP pretest scores.

**H2:** Students using the LABL CAI reading tutorial will improve their DRP exam scores (from pretest to posttest) a significantly greater amount than students in the control group will improve their DRP exam scores.

**Oral Readings**

**H3:** Students using the LABL CAI reading tutorial will significantly improve their reading accuracy rate from pretest to posttest reading.

**H4:** Students using the LABL CAI reading tutorial will significantly improve their reading acceptability rate from pretest to posttest reading.

**Interviews**

Research Question: Does the interview data from interviews with the participating students corroborate the DRP test findings and provide support that the improvements in the students’ reading ability can be partially attributed to using design of the LABL CAI reading tutorial?

Research Question 2: Does completing the LBAL CAI program help poor readers learn?
Research Question 3: Does the design of the LBAI CAI improve learner performance?

**Procedures**

This section describes the procedures followed in administering tests and interviews and collecting the data.

**DRP Tests**

The Degree of Reading Power (DRP) test is a criterion-referenced, standardized, reading comprehension examination. Two statistically equivalent forms of the DRP were administered for the pretest and posttest. All 4th and 5th grade students in attendance at the school were administered the DRP pretest in the Fall semester and the DRP posttest at the end of the subsequent Spring semester. In accordance with the DRP testing procedures, students were given an unlimited time to complete the test, although most turned in their examination within one to 1.5 hours.

**Structured Student Interviews**

At the end of the school year, a structured interview was conducted by the researcher, one-on-one with each of the 19 students in the treatment group. Each interview took approximately 45 minutes to complete. Each student was removed from his or her homeroom class and the researcher orally conducted the structured interview, reading each of the items and recording the students’ verbal responses. Because the researcher conducted the interview orally and recorded the students’ verbal responses, possible concerns related to the students’ reading and/or writing abilities, or lack there of, were alleviated. This was a concern since the students were chosen to participate in the
study because they were poor readers at the beginning of the school year. In addition to the researcher explaining the 4-point response scale to the students during the interview, the students were given a printout of the scale for their reference as they completed the interview. Several of the quantitative items were followed by related qualitative questions asking the students to explain “why” they answered the previous quantitative items as they did. Besides gathering information, the quantitative items served as prompts for the more probing “why” discussion items. If a student indicated that he/she did not understand the meaning of an item, the researcher would clarify. In addition, if a student’s response to the “why” questions seemed to contradict his/her response to the related statement, the researcher would discuss and clarify the meaning of that particular item with the student to ensure the student’s comprehension. This also allowed the researcher to clarify her understanding of the students’ comments.

**Oral Readings**

When the students were assigned to the LABL reading tutorial, they completed the pretreatment oral reading. Students were individually taken into a room adjacent to the computer lab, where the reading specialist asked them to read the two passages. A tape recorder was used to record the session. If the students asked questions about what they were supposed to do, the reading specialist would give further directions; otherwise, she did not comment on the students’ reading until they had completed orally reading both passages. Any comments on the part of the students or the reading specialist during the oral reading were preserved in the recordings evaluated by the independent raters.
The oral readings for each passage were digitized in a separate .wav file. All of the files for Passage A pre and post readings were randomly numbered, named accordingly and written to compact disc in random order to prevent rater bias. The same procedure was followed with Passage B readings. In the end, the raters each received one disc that contained all of the Passage A readings and another that contained all of the Passage B readings.

The raters were two public school 4th grade teachers in another state, who had no contact with any participants in this study. The raters were not given any specific information regarding the students (name, grade, gender, etc.) or the timing (pre- or post-treatment) of each oral reading, other than what they heard in the recording. No information was provided that would identify two readings as being by the same student, other than possible voice recognition. The raters knew that the readers were 4\textsuperscript{th} or 5\textsuperscript{th} graders that attended a reading program and that there were pre and post-program readings. The readings were evaluated using the qualitative reading inventory running record (RR), as describe in the measures section. Both teachers were formally trained in this method of miscue analysis, as well as experienced in using it in their own classrooms.

The oral readings were rated for accuracy and acceptability. To establish inter-rater reliability, both raters initially evaluated the first six random recordings for each passage. Pearson’s product-moment correlations were computed for accuracy ($r = .986$, $p < .01$) and acceptability ($r = .997$, $p < .01$). The highly positive and significant correlations mean that inter-rater reliability is high on both measures (Judd et al. 1991). For a visual comparison
of the duplicate ratings by raters 1 & 2, see Figure 5 and Figure 6. The raters then divided the remaining recordings, each rating a portion of the remaining oral readings of Passage A and Passage B, respectively. Two of the recordings of Passage A cut-off the end of the oral reading, so the denominator (total number of words in the passage) was adjusted downward to the number of words recorded in determining the ratings for these passages.

**Interrater Reliability**

**Accuracy Rating of Oral Reading**

![Graph showing accuracy ratings for oral readings by raters 1 and 2.](image)

**Figure 5: Inter-rater Reliability: Accuracy Ratings on Sample by Raters 1 & 2**
Interrater Reliability

Acceptability Rating of Oral Readings

Oral Reading - Random Passage

Figure 6: Inter-rater Reliability-Acceptability Ratings on Sample by Raters 1 & 2

Analysis

DRP Scores

A repeated measures analysis was conducted to analyze the difference in the DRP pretest scores and DRP posttest scores, by student. In a repeated measures design, a variable is measured two or more times for each participant, thus requiring fewer participants. In this case, the variable "DRP score" is measured twice; the pretest is the first measure and the posttest is the second measure. Furthermore, because the same participant is repeatedly measured, the repeated measures analysis has the distinct advantage of removing the variance from the error term that results from variability due to individual differences between participants not related to the treatment (Norusis 1990;
Shavelson 1988). Removing this portion from the error variance increases the power of the statistical test for significance.

One of the possible problems with repeated measure is an order or learning effect. A learning effect may occur in repetitive tasks where the mere act of repetition, independent of the treatment(s), causes improvement in the student. This research design controls for a learning effect in two ways. First, although the DRP pretest and posttest were statistically equivalent forms, they were factually different. And, second, the treatment group is compared to the control group that also took the identical DRP pretest and posttest.

**Effect sizes.** Effect sizes help quantify the strength of a significant effect. The raw effect size, computed as the treatment group mean (mean_t) minus the control group mean (mean_C), provides an index that is independent of the sample size of a study and that is stated in the same units of measure as the dependent variable (Abelson 1995), and thus is meaningful in the context of a particular study. The standardized effect size $d$ provides an index in units of variability (standard deviations) that is independent of original measurement units, making it statistically comparable to the effect sizes found in other studies with different measures. Cohen (1988) states that the standardized effect size provides a needed index of “the degree of departure from the null hypothesis of the alternate hypothesis... (Cohen 1988, p. 20).” $d$ is computed as the raw effect size divided by either the control group standard deviation ($sd_C$) or the pooled standard deviation ($sd_p$). Using the $sd_p$ results in a better effect size estimator because the $sd_C$ is biased (Cortina & Nouri 2000) and it has a larger sampling error than $sd_p$ (Hunter & Schmidt
1990). Thus, the $d$ is computed using as the $sd_p$ denominator. In terms of size, Cohen (1988) suggests the following heuristics for interpreting effect sizes: $d = .2$ is small, $d = .5$ is medium, and $d = .8$ is large. Of course, these conventions need to be considered relative to the area of behavioral science and the specific phenomenon being investigated.

**Structured Student Interviews**

The student interview questionnaires consisted of closed-ended and open-ended items. The items are grouped by underlying constructs the questions were intended to measure. Negatively worded statements were included to control for positive response bias. The frequencies and modes for the close-ended items and questions are presented and discussed in the results section. For each of the open-ended questions, each student’s response is presented with the response to the associated closed-ended question. These responses are summarized and discussed in the results section.

**Oral Readings**

A paired samples $t$-Test was conducted to analyze the difference in the accuracy and acceptability scores from pretest to posttest. A paired samples $t$-Test, also called a dependent samples $t$, is appropriate because the pretest and posttest samples are not independent (Shavelson 1988), i.e. a within-subjects design is used in which the same students are pretested and posttested to measure individual improvement. Rather than analyzing the pre and posttest scores separately, a paired samples $t$-Test analyzes the difference between the scores computed for each participant. Because the same students are measured pre and post treatment, the within-subjects design reduces the error
variability due to individual differences, making the design more powerful than a between-subjects design.

Results

**DRP Scores**

The DRP is a standardized examination of reading comprehension. Two statistically equivalent forms of the exam were administered as pretest and posttest, in the Fall and subsequent Spring semesters, respectively. A repeated measures analysis resulted in the following.

**Between-Subjects Effects.** As expected, the mean DRP pre (40.17) and post (41.26) test scores of the control group are statistically significantly greater than the mean DRP pre (9.22) and post (22.83) scores of the treatment group. This result is not surprising because the treatment group consisted of poor readers, while the control group did not. Of more interest in this study is the within-subject effect.

**Within-subject effect.** In general, the students’ post DRP scores are significantly greater than their pre DRP scores at p<.001, indicating that reading comprehension improved in both groups over the period (average increase from pre to post is 14.7). Of more interest, the interaction effect between treatment and time is also significant. The pre-post difference scores, indicating the students’ improvement in reading comprehension, are significantly greater for the treatment group (mean increase is 13.61) as compared to the control group (mean increase is 1.09). In other words, the treatment group improved their reading comprehension significantly more than the control group at the p<.005 level.
### DRP Reading Comprehension Scores

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Pre DRP*</th>
<th>Post DRP*</th>
<th>Incr</th>
<th>F</th>
<th>p-val</th>
<th>% Incr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treat. Tutorial</td>
<td>18</td>
<td>9.22 (22.91)</td>
<td>22.83 (18.33)</td>
<td>13.61</td>
<td>8.23</td>
<td>.005*</td>
<td>147.61%</td>
</tr>
<tr>
<td>Control: No Tutorial</td>
<td>53</td>
<td>40.17 (15.14)</td>
<td>41.26 (17.69)</td>
<td>1.09</td>
<td></td>
<td></td>
<td>2.71%</td>
</tr>
<tr>
<td>Total sample</td>
<td>71</td>
<td>32.32 (21.95)</td>
<td>36.59 (19.47)</td>
<td>14.7</td>
<td>11.36</td>
<td>.001*</td>
<td>45.48%</td>
</tr>
</tbody>
</table>

*Numbers are means (standard deviations).

Figure 7: Repeated Measures Analysis of DRP Test Scores for Treatment vs. Control

The groups' performance on the pre and post DRP are statistically significantly different, but the treatment group is improving more. In fact, the treatment group improved their average DRP score by 147%, more than doubling their pretest scores on the posttest. If you look at the standard deviations for the control and treatment groups, you notice that the standard deviations of the test scores for the pretest are much different for the two groups (22.91 vs. 15.14), an indication of their heterogeneity. However, the standard deviations for the posttest DRP scores of the two groups are much more similar.
(18.33 vs. 17.69), indicating that the groups are becoming more homogeneous. See Figure 7 for the pretest and posttest comparison.

**Effect sizes.** Effect sizes help quantify the strength of a significant effect. The raw effect size, computed as $\text{mean}_T \cdot \text{mean}_C = 13.61 - 1.09 = 12.49$ DRP units. The standardized effect size $d$ is $12.69 / 16.8 = .75$. Thus, the means of the treatment and control groups differ by .75 standard deviations, a medium to high effect within Cohen's conventions (Cohen 1988).

**Structured Student Interviews**

Each of the students in the treatment group completed a structured interview with the researcher, comprised of open-ended and closed-ended items. The majority of the closed-ended items were rated on a 4-point scale, as previously discussed in the analysis section. The results indicate that the students perceived that using the LBAL CAI improved their reading skills, reduced distractions, improved concentration, and taught useful strategies. In addition, students overwhelmingly perceived the hints, feedback, self-pace, practice activities, mastery learning features, control of repetition and expository learning in the CAI were all helpful to learning. Moreover, students perceived that the video-streamed instructor in the CAI was their personal tutor. Even though a majority of students preferred working on the CAI to their homeroom teachers, over 25 percent preferred the opposite. These results can be viewed in Table 5 and Table 6, which display the wording, intended construct, response frequencies, mode and mean for each item.
Table 5: Structured Student Interviews – Closed-ended Items 1-24

<table>
<thead>
<tr>
<th>Construct</th>
<th>Interview Item</th>
<th>Response Frequency</th>
<th>Mode</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Importance of reading</td>
<td>1. Knowing how to read is NOT important. **</td>
<td>13 5 1 1</td>
<td>1</td>
<td>1.37</td>
</tr>
<tr>
<td></td>
<td>4. Learning to read is very important to me.</td>
<td>3 16 4 1</td>
<td>4</td>
<td>3.84</td>
</tr>
<tr>
<td></td>
<td>2. I think I can be a good reader.</td>
<td>6 13 4 1</td>
<td>4</td>
<td>3.88</td>
</tr>
<tr>
<td>Self-efficacy</td>
<td>3. I will never be good at reading long, multi-syllable words. **</td>
<td>13 3 3 1</td>
<td>1</td>
<td>1.47</td>
</tr>
<tr>
<td>Did using LBAL improve reading skills?</td>
<td>5. I improved my reading by using the Larrabee program.</td>
<td>5 14 4 1</td>
<td>1</td>
<td>3.74</td>
</tr>
<tr>
<td></td>
<td>6. From the Larrabee program, I did not learn any new</td>
<td>13 6 1 1</td>
<td>1</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>7. The Larrabee program taught me to read long multi-syllable words.</td>
<td>1 4 14 4</td>
<td>1</td>
<td>3.68</td>
</tr>
<tr>
<td></td>
<td>8. I can not spell any better than I could before I used the Larrabee program. **</td>
<td>13 4 2 1</td>
<td>1</td>
<td>1.53</td>
</tr>
<tr>
<td></td>
<td>9. After using the Larrabee program, I can understand what I read better.</td>
<td>4 15 4 1</td>
<td>1</td>
<td>3.79</td>
</tr>
<tr>
<td>Does the computer reduce distractions?</td>
<td>10. I would rather practice reading with my teacher than on the computer. Why?</td>
<td>5 9 1 4 3</td>
<td>4</td>
<td>2.21</td>
</tr>
<tr>
<td></td>
<td>11. I like learning on the computer. Why?</td>
<td>1 1 1 1 18 4</td>
<td>1</td>
<td>3.68</td>
</tr>
<tr>
<td></td>
<td>12. When working on the computer, I don’t have to worry about what the other kids think about my reading.</td>
<td>1 1 4 13 4</td>
<td>1</td>
<td>3.53</td>
</tr>
<tr>
<td></td>
<td>13. Is it more embarrassing to make a mistake in class or to make a mistake on the computer? 1 = In Class 2 = PComputer 3 = Same Why?</td>
<td>16 3 1 1</td>
<td>1</td>
<td>1.01</td>
</tr>
<tr>
<td>Does the computer improve concentration?</td>
<td>14. Working on the computer makes it harder to focus on my lessons. Why? **</td>
<td>14 4 1 1</td>
<td>1</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td>15. I can concentrate better when working on the computer than I can concentrate when working by myself with my teacher. Why?</td>
<td>3 2 6 8 4</td>
<td>4</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>16. When learning to read, the computer helps me concentrate better than I can concentrate in the classroom. Why?</td>
<td>1 4 7 7 3 4</td>
<td>4</td>
<td>3.05</td>
</tr>
<tr>
<td>Do students perceive the LBAL CAI as their personal tutor?</td>
<td>17. Who teaches you to read when you go to the computer reading lab?</td>
<td>2 14 1 2 2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>18. In the Larrabee program, I feel like Mr. Larrabee is my private teacher.</td>
<td>1 4 14 4</td>
<td>4</td>
<td>3.68</td>
</tr>
<tr>
<td></td>
<td>19. Learning from a cartoon character on the computer is better than learning from a real person on the computer. Why? **</td>
<td>6 7 2 4 2</td>
<td>2</td>
<td>2.21</td>
</tr>
<tr>
<td></td>
<td>20. Working with a real live teacher 1-on-1 is better than working with a teacher like Mr. Larrabee on the computer. Why? **</td>
<td>7 5 3 4 1</td>
<td>2</td>
<td>2.21</td>
</tr>
<tr>
<td>Mastery learning</td>
<td>21. When I get an answer wrong, I like trying again before I’m given the right answer.</td>
<td>1 1 2 15 4</td>
<td>4</td>
<td>3.63</td>
</tr>
<tr>
<td></td>
<td>22. Doing lessons again and again until I get everything right helps me learn.</td>
<td>1 2 16 4</td>
<td>4</td>
<td>3.79</td>
</tr>
<tr>
<td></td>
<td>23. If I am wrong, I do not want to try again. **</td>
<td>13 3 2 1 1</td>
<td>1</td>
<td>1.53</td>
</tr>
<tr>
<td></td>
<td>24. Coming back to words I missed makes me a better reader.</td>
<td>4 15 4 1</td>
<td>4</td>
<td>3.79</td>
</tr>
</tbody>
</table>
Table 6: Structured Student Interviews -- Closed-ended Items 25 to 47

<table>
<thead>
<tr>
<th>Construct</th>
<th>Interview Item</th>
<th>Response Frequency</th>
<th>Mode</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Self-paced learning</td>
<td>25. Being able to work as slow or as fast as I want helps me learn.</td>
<td>1</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Control</td>
<td>26. I like that I am able to make Mr. Larrabee repeat what he says whenever I want to.</td>
<td>2</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>26. Do you make Mr. Larrabee repeat what he says more (3), more less (1) or the same (2) amount as you would ask your teacher?</td>
<td>3</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>27. When the Larrabee program was hard for me, I wanted to quit. **</td>
<td>9</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>28. The Larrabee program challenged me to learn more.</td>
<td>1</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>29. If a lesson is easy for me, it is boring.</td>
<td>6</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>30. Working on the Larrabee program makes me feel successful. Why??</td>
<td>2</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td>Feedback in LBAL helpful</td>
<td>32. The hints Mr. Larrabee gives when I get a word wrong are not helpful. Why? **</td>
<td>10</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>33. When I get a word wrong, Mr. Larrabee helps me learn by saying the word again very slowly.</td>
<td>5</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>34. The Larrabee program does not help me understand why my answers are wrong. **</td>
<td>13</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>35. I learn more when I find out right away whether my answers are right or wrong. Why?</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>36. The Larrabee program helped me by teaching me how to pronounce the sounds of letters that I did not know how to say before. What letters did you learn?</td>
<td>1</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>37. Mr. Larrabee showing me how to make the sounds of letters with my mouth and tongue was helpful to me.</td>
<td>1</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>38. Learning about the voiced and (unvoiced) sounds did not help me. **</td>
<td>13</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Multi-sensory activities</td>
<td>41. Doing many different activities for the same lesson did not help me learn the lesson better than if I had just done one activity. **</td>
<td>14</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>39. The Larrabee program teaches me strategies or tricks that help me know how to pronounce words.</td>
<td>5</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>42. The Larrabee program taught me how to make the right choices for spelling a word.</td>
<td>6</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>43. Mr. Larrabee did not teach me why words are said the way they are. **</td>
<td>9</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>44. I did not learn why words are spelled the way they are from the Larrabee program. **</td>
<td>11</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>45. With the strategies I have learned from the Larrabee program, I can read new words on my own.</td>
<td>3</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>46. The computer is not fun to use. Why?</td>
<td>18</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Computer novelty</td>
<td>47. The best thing about the Larrabee program is using the computer. Why? **</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Several of the closed-ended items in the structured student interview were followed up with "Why?" questions. The responses to these questions were further supportive of
the perceived effectiveness of the CAI in helping students learn. The responses to some of these questions are discussed here.

For example, in response to Item 10, “I would rather practice reading with my teacher than on the computer. Why?,” students who agreed (responded 3 or 4) commented that they liked talking and interacting with their teacher. The 75 percent of students who disagreed with item 10 (responded 1 or 2) divulged that they preferred the computer for a myriad of reasons including: not getting along well with their teachers, better explanation from the on-screen instructor than their teacher, opportunity to master lessons, multiple chances provided for correctly responding to questions, and more helpful strategies for sounding out words. All of the students responses and comments are presented in Table 7.

In response to item 11, “I like learning on the computer. Why?,” 17 of 19 students agreed or strongly agreed. Eight of these students indicated that they like working on the computer or that the computer was fun. Eleven students said they liked it because they were going to learn something new or more than they would otherwise, citing multiple chances, feedback, and learning to read better as reasons. One student stated, “We learn a little bit more than with the teacher.” Another student indicated the importance of repetition, mastery and student-control of review by stating, “… Even if I miss it one time I can do it again and again and again.” This indicates that the students perceive the CAI features are helping them. In contrast, 2 students indicated the did not like learning on the computer, because, “the computer doesn’t tell you that much,” and “you could do much better (doing) something else off the computer.”
Table 7: Student Open-ended Responses to Item 10

Prompt: If the statement is very different from you, choose 1 for Strongly Disagree.
If the statement is little different from you, choose 2 for Disagree.
If the statement is little like you, choose 3 for Agree.
If the statement is a lot like you, choose 4 for Strongly Agree.

<table>
<thead>
<tr>
<th>Interview</th>
<th>10. I would rather practice reading with my teacher than on the computer. Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student</td>
<td>Code</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>2</td>
</tr>
</tbody>
</table>

Mode 2
Item 13 asked, “Is it more embarrassing to make a mistake in class or to make a mistake on the computer? Why?” In response, 16 students responded “in class,” zero responded on the computer and three responded there was no difference. An unusual trio, the latter three students all indicated that it was not embarrassing to make a mistake or “I don’t care what other kids think.” The other 16 indicated that working on the computer removed the embarrassment factor of other kids.

In the open-ended responses to items 14, 15 and 16, the students indicated an that they perceived that the CAI helped increase their concentration and reduce outside distractions. Although the students were not all able to explain why, some indicated being able to see and hear better, lack of outside talking, use of headphones and interactivity as reasons for better concentration.

**Multisensory activities**

The LBAL CAI includes seven different multisensory, multimedia learning activities in the lessons: word building, listen and find, reading, writing, spelling, two-syllable words, and vowel sound stick (VSS). To probe if the multiple, multisensory activities were helpful to learning, the students were asked a series of questions about these activities to identify whether or not the different activities helped the students learn to read, and to what extent. The responses to these questions are summarized in Table 8. First they were asked to identify, “Which activities helped you learn to read?” The 19 students each identified an average of 5.74 activities as helpful, with 6 activities be the most frequently selected number (mode). Between 12 (for the VSS activity) and 19 (for the listen and find activity) students chose any specific activity as helpful, with an
average of 15.43 students selecting each activity as helpful. With regard to the VSS activity, it should be noted that the remaining 7 students had not progressed to the lessons with the VSS activity so they had not used that activity. There were also four students who had not used the two-syllable words activity.

Table 8: Student Evaluation of Multisensory Activities

<table>
<thead>
<tr>
<th>Learning Activities</th>
<th>Helped</th>
<th>Extent Helped</th>
<th>Helped the Most</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes (#) (%)</td>
<td>No (#) (%)</td>
<td>None (#) (%)</td>
</tr>
<tr>
<td>Word Building</td>
<td>13 69</td>
<td>6 32</td>
<td>8 42</td>
</tr>
<tr>
<td>Listen and Find</td>
<td>19 100</td>
<td>7 37</td>
<td>12 63</td>
</tr>
<tr>
<td>Reading</td>
<td>16 84</td>
<td>3 16</td>
<td>1 5</td>
</tr>
<tr>
<td>Writing</td>
<td>17 89</td>
<td>2 11</td>
<td>4 21</td>
</tr>
<tr>
<td>Spelling</td>
<td>17 89</td>
<td>2 11</td>
<td>1 5</td>
</tr>
<tr>
<td>2-syllable Words</td>
<td>15 100</td>
<td>0 0</td>
<td>1 7</td>
</tr>
<tr>
<td>Vowel Sound Stick</td>
<td>12 100</td>
<td>0 0</td>
<td></td>
</tr>
</tbody>
</table>

Second, the students were asked to identify the extent to which the activities that helped them learn to read helped: “a little”, “some”, or “a lot”. For all of the activities, 68% to 100% of the students participating in the learning activity rated the activities as helping “some” or “a lot”. With the exception of the word building activity, the majority of students rated all of the activities as helping them “a lot.”

Third, the students were asked to identify which activity helped them the most and why they chose that activity as the most helpful. The results were relatively balanced, ranging from one to four students selecting any activity as the most helpful. In summary, four different activities were each chosen by three students, while the remaining three activities were selected by four, two and one student, respectively. The listen and find activity was selected by the most (4) students. The results demonstrate that each of the
multisensory activities was the most beneficial for at least one student, meeting that student's perceptual preferences. These results may be partially biased since four of the students had not used the two-syllable words activity, while seven students had not used the VSS activity. In conclusion, the responses to this series of questions indicates that the students perceived the multisensory activities to be beneficial to their learning, with different students preferring different multisensory activities.

**Oral Readings**

As expected, the mean accuracy and acceptability ratings of the oral readings for both Passages A and B increased from pre to post treatment. For Passage A, the improvement in the mean acceptability rate of 4.24 percentage points from 90.76 to 95 was statistically significant (p < .045). Although the mean accuracy rating for Passage A increased 3.18 percentage points from 89.47 to 92.65, the improvement was not statistically significant (p < .154). For passage B, the paired samples t-Test confirmed that the participating students scored significantly better accuracy and acceptability ratings on their post oral readings as compared to their pre oral readings. On average, the students significantly improved their accuracy rates 17.82 percentage points, from 49.06 to 66.08 (p < .008), and their acceptability rates 18 percentage points, from 50 to 68 (p < .008), for a 36 percent improvement in each. Moreover, the standard deviations for each of the ratings decreased, indicating that the oral reading abilities of the participating students became more homogenous over time. See Table 9 for the results of data analysis.
Table 9: Results of Paired Sample t-Test on Oral Reading Ratings

<table>
<thead>
<tr>
<th>Passage</th>
<th>N</th>
<th>Accuracy %</th>
<th></th>
<th></th>
<th>Acceptability %</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre*</td>
<td>Post*</td>
<td>Diff</td>
<td>p</td>
<td>Pre*</td>
</tr>
<tr>
<td>A (short)</td>
<td>17</td>
<td>89.47 (8.98)</td>
<td>92.65 (7.85)</td>
<td>3.18</td>
<td>.154</td>
<td>90.76 (7.90)</td>
</tr>
<tr>
<td>B (long)</td>
<td>17</td>
<td>49.06 (36.3)</td>
<td>66.08 (26.9)</td>
<td>17.82</td>
<td>.008</td>
<td>50.00 (37.2)</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>34</td>
<td>69.26 (33.1)</td>
<td>79.76 (23.47)</td>
<td>10.5</td>
<td>.005</td>
<td>70.38 (33.6)</td>
</tr>
</tbody>
</table>

* mean (sd)

Discussion

The results of the field study indicate that the LBAL CAI helped poor readers learn to read. Furthermore, the responses to the structured student interviews support the benefits of CAI design in supporting learners and instructional methods. Specifically, active participation, increased focus/decreased distractions, multisensory learning, expository learning, mastery learning and immediate feedback were each revealed as important to principles for CAI design.
CHAPTER 6 -- CAI DESIGN PRINCIPLES & METHODOLOGY

Based on the research conducted, a set of CAI design principles are proposed and described. These principles focus on the instructional design elements important to support and improve learning by supporting the development of learners' mental schemas.

CAI Design Principles for Improving Learning

Principle 1: Integrate instruction, practice, assessment and feedback.

If the learning objective is to develop new knowledge or skills, it is recommended that the CAI design integrate instruction, practice, assessment, and feedback. Each of these four components provides a significant contribution to learners' effective development of accurate mental models. However, many existing CAI lack one or more. Many may be surprised, for example, that drill-and-practice CAI programs often lack an instructional component. The key that many do not realize is that drill-and-practice alone does not teach new knowledge; it provides practice and reinforcement of existing knowledge. Instruction is key to imparting knowledge. While practice is an appropriate and important complement to instruction, it should not be expected to take the place of instruction. Furthermore, even drill-and-practice programs should incorporate assessment and feedback on the practice activities. Assessment is needed to give feedback, and feedback is necessary to help learners test the accuracy and application of their mental models. Moreover, practice, assessment, and feedback are important components for learners to revise, refine and strengthen their mental models of the knowledge provided by instruction.
Principle 2: Instruct.

Design CAI to integrate instruction that

- explicitly teaches the knowledge needed to achieve the learning objective
- in small, incremental segments (elements or concepts)
- that are sequenced to accommodate logical dependencies in the information.

Furthermore, present the instructional material in a multisensory, multimedia format that actively engages the learners.

First, facilitate expository learning of the required base knowledge by providing explicit instruction of that knowledge. Expository learning is an efficient method to for learners to develop their “prototype” mental models based on knowing, while subsequent practice and review activities provide the opportunity to test and revise those models. In addition, segment the explicit instruction into small incremental elements or chunks of information. In the resultant expository learning, cognitive load is decreased because working memory is allowed to process the elements separately, rather than all at the same time. Connections between the elements can be learned separately from learning the elements; either before (advanced organizer) and/or after (post-structure) the elements are learned. In contrast, discovery learning requires connections to be made between several different elements, while the elements are being discovered causing a high cognitive load because many different elements must be processed at the same time. This is more difficult and may not be possible for some learners. In addition, although discovery learning can result in effective learning for some, it is prone to mis-discovery (i.e., learning the wrong thing or making the wrong inference) since it is an inductive process.
Thus, explicit instruction is important in CAI design. Segmentation can allow
eXperienced learners to access the specific topics they need in circumstances that require
just-in-time learning or a small portion of the instruction covered by the CAI.
Furthermore, the segmentation enables the integration and interaction of the instruction
with practice, assessment and feedback.

Next, identify the logical dependencies in the knowledge and structure the CAI
sequence of the learning experience to accommodate those dependencies. Organize
learning materials for the learner in structured, meaningful manner that promotes
cumulative and sequential progress to achieving the learning objectives. In designing
CAI, designers should not expect learners to be able to choose the best order for
developing new knowledge or skills. Ordering of the lessons is important. From a logical
perspective, novices do not know enough to know the best order for learning material.
Consequently, determining the most appropriate sequence for learning is the
responsibility of the instructional design, and this guidance should be incorporated in the
CAI. The instructional analysis should provide a sequence if relevant, based on the
learner and the context. Assuming knowledge or skill is cumulative, prerequisite
knowledge should be sequenced before it is needed for later lessons. In contrast, a learner
experienced in the domain, may have specific learning needs and will probably know
more about what they need to learn than a novice will. Depending on the characteristics
of the learner, the predetermined sequence of lessons may be imposed or suggested;
however, ultimately there should be some method of overriding the path.
Finally, present the instructional material in a multisensory, multimedia format. Multimedia instruction can be designed to promote multisensory learning, which can facilitate learning by reducing the cognitive load of a learning task and strengthening the development of mental schemas by engaging multiple perceptions.

Principle 3: Practice

Design the CAI to integrate practice with the instruction. Design the practice to:

- activate and test learners' mental schemas from multiple perspectives

- occur in frequent and short practice sessions or activities that are integral to the instructional segments, and

- use multimedia to activate multisensory learning.

To maintain the learners' active participation in the learning process, design CAI so that learners are frequently required to apply and test their mental schema for the learning objective. Active participation of students may include both overt, visible behavior, and covert, unseen thinking behavior by students (Hashway 1998). A CAI should be designed to maintain the learners active participation in the learning process. This necessitates that the learners focus on the learning task. As discussed in Chapter 3, research has shown that an interactive and multimedia user interface can increase student focus. More importantly, frequent, thought-provoking interactive activities and questions integrated with timely feedback encourages learners to actively process information.

In designing the practice activities, use a variety of approaches (top-down, bottom-up, etc.) and/or learning activities to focus the learner's attention from multiple perceptual modalities (e.g., visual, aural, kinesthetic, etc.) on knowledge that the learner needs to achieve the learning objective. This will support the development of learners
mental models with multiple forms of practice and review activities. Design practice activities into CAI to encourage learners to review, test and strengthen their mental schema of the learning objective. Different forms of practice, examples and review activities should be included for the learner who needs another way of learning. A learner who is having trouble understanding may need the concepts explained in a different way. For example, in the LBAL reading tutorial there are several different activities that practice and test different aspects of reading. There are multiple activities to practice encoding (translating from sound to text) words. In one, the on-screen instructor says a word, and the student selects that word from four written on the screen. In another, the student “builds” the word he/she hears by dragging phonemes from a limited selection. In others, the student spells the word by typing or selects an on-screen illustration of the word from four choices. Each activity activates the learners attention from a different perspective.

Design the multisensory activities to focus the learners’ attention on relevant information, but be careful not to split the learners’ attention unnecessarily, or add extrinsic cognitive load. If designed properly, multisensory instructional activities have the potential to increase the capacity of working memory to process information by engaging multiple senses. However, if the multimedia/multisensory activities split the learners attention or overload the senses the design can create extrinsic cognitive load, distracting the learner and reducing the cognitive resources focused on achieving the learning objective. So, multisensory activities should be designed to:

1. support the learners’ unique perceptual preferences,
2. support, and possibly increase, learners capacity to process instructional
   information by integrating information in a multisensory format, and
3. facilitate the development of their mental models of the learning objective by
   engaging all of the learners' senses.

Principle 4: Assess

Design CAI to integrate assessment with the instruction and practice activities.
Assessment is important because it provides a basis to provide feedback to the learner on
their learning. As such, it should be designed as an integral component of the CAI. As
with instruction and practice, design CAI to frequently evaluate the learners' performances (learning). The assessment can be provided directly and explicitly by
testing the learners, then recording and evaluating their responses. Or, the CAI design can
provide opportunities for learners to assess their own performance by providing analyses
and evaluations of practice activities, thereby allowing the learners to assess their own
performance in comparison. The former requires separate feedback to be given to
learners on their performance, while the latter is a combination of self-assessment and
feedback. How to assess learning is a complex issue outside the purview of this study.
However, one point will be mentioned. Whatever the method implemented, assessment
should measure the learning objectives of the CAI design.

Principle 5: Feedback

Design CAI to integrate feedback with the instruction, practice and assessment
components. Preferably, feedback should be timely and performance-specific.
Furthermore, CAI should deliver feedback in structured incremental stages that culminate
with explanatory feedback. Feedback should inform the learners regarding their performance in such a way that it promotes the development of the learners' mental models. The presentation and form of feedback should be informative and encourage learners to think and process the information. The goal of feedback is to help learners test and, if necessary, revise, their mental models of the learning objective. Feedback can be varied by time (delay between response and receiving feedback) and content (structure and information provided).

There are many possible levels of feedback content (e.g., KR, KRH, KRC, and KRE). One CAI design strategy is to provide multiple chances to the learner, providing more feedback information immediately after each missed attempt. In this way, learners are encouraged to be cognitively engaged in processing the feedback (i.e., an active participant), receiving additional information after each attempt to help them correct their response and revise/develop their mental model for the problem. In the end, the best practice is to provide KRE feedback that identifies the correct response and provides explanation of correct response, and maybe why the others are wrong. This provides learners with complete information to prevent misinterpretation in developing their mental models correctly. It should be noted that an individual may "know" something, but their "knowledge" may be incorrect. Explicit instruction and feedback should mitigate development of misconceptions in mental models. There is a balance between the number of tries made and learner frustration. This also relates to the content of the feedback. Consider providing the learner some control of the number of tries, for
example, instituting the option to have from two to five chances with a "Try Again" selection.

Unlike a human teacher, CAI cannot interpret body language to judge whether a student is understanding the instruction or feedback. A CAI must rely on the learner's performance. Normally, if a human teacher interprets a lack of understanding by the learner, the human will be expected to adapt the feedback response to try to gain understanding. Another approach or different information will be given. The teacher does not continually repeat himself/herself verbatim if the student makes the same error, and if he/she does, the repetitious feedback would likely become annoying and unconstructive. In the same circumstances, CAI would likely have the same result. Therefore, CAI feedback should be designed in structured, cumulative stages that culminate in feedback that provides knowledge of the correct response combined with an explanation of why the correct response is correct.

Principle 6: Support mastery learning

Design CAI to facilitate sequential and cumulative mastery learning of the knowledge requisite to the learning objective(s). The objective of mastery learning is to ensure that the learner gains the prerequisite skills and knowledge at each stage before preceding to lessons on knowledge dependent on the prerequisite skills. Mastery can be supported by iterations of instruction, practice, assessment, and feedback. A structured sequence of learning based on logical dependencies in the learning task is required to identify the prerequisites for each lesson. In addition, alternate instruction and practice activities can help learners gain understanding. Mastery improves learning, in part, by
decreasing the cognitive load on the learners. Because learners develop their mental schema for the prerequisite knowledge, more cognitive effort can be focused on the more advanced concepts without the need to expend cognitive resources on understanding the prerequisites. Consequently, mastery learning supports the development of mental schemas (learning) and is beneficial to any CAI design.

Principle 7: Focus cognitive effort

Design CAI to focus the learners’ cognitive efforts on the learning task, while minimizing the cognitive load on the learner. This involves minimizing the intrinsic cognitive load of the instructional design, as well as mitigating extrinsic cognitive load (i.e., distractions). As previously discussed, cognitive load is an important issue for learning since each individual has limited cognitive resources to process information. The cognitive load of the learning task (intrinsic cognitive load) is important, as is the cognitive load caused by distractions (extrinsic cognitive load). Minimizing cognitive load includes consideration of the interface design, presentation of instruction and materials, timeliness of feedback and the use of multimedia and multisensory activities. Regarding intrinsic cognitive load, the instruction should present the information in small, cumulative bits (elements), if possible, to make the learning task easier. In addition, care must be taken not to add cognitive load extrinsic to the learning process. Cognitive load is extrinsic if the load does not contribute to achieving the learning objective. This can be achieved by carefully integrating information for the learner in a multisensory format, and avoiding causing the learner to integrate information, especially repetitive information, from disparate sources (Sweller 1999). Thus, if possible, the CAI
design should avoid splitting the learners’ attention or distracting attention from the learning objective.

Principle 8: Personalize CAI

Research shows that personal tutoring improves student achievement (Bloom 1997; Newby et al. 2000), so design CAI to be personal tutor for each learner.

Personalization has many possible design aspects, these include:

- personalizing the instruction, practice, assessment and feedback activities,
- providing learners some controls of the learning experience and process,
- providing administrative controls for customizing the learning environment, and
- designing an adaptable CAI interface.

Personalize Instruction, Practice, Assessment and Feedback.

Design CAI to personalize instruction, practice, assessment and feedback to focus on individual students’ learning needs. To dynamically personalize the CAI for individual learners’ will require a combination of pre-assessment and ongoing evaluation of the students’ performance. Consider designing the CAI instruction, practice and feedback in modules that can be combined for a personalized learning experience, based on the learners needs.

To personalize the instruction, the pre-assessment should provide a measure of the individual learner’s prior knowledge and skill level, identifying the content (e.g., lessons or learning modules) that a learner needs or has already mastered. In the case of just-in-time training, an alternative to pre-assessment is to provide learners with some control of selecting the content they need, so that they can directly select the topics of interest. This
may also be a strategy for practice and review objectives, allowing learners to select the lessons or topics they need help with.

Personalization of practice and feedback requires some type of assessment to evaluate student progress. Preferably, this assessment would be conducted and tracked by the CAI. Alternatively, the assessment can be internally conducted by the learner, but this will increase the cognitive load on the learner to evaluate and manage his or her own progress. In either case, KRE feedback should ultimately be provided, although it may be the final level in a cumulative series, as recommended in Principle 5. If the CAI is conducting the assessment, corrective feedback can be personalized to a greater extent and respond to the specific errors made by the learner.

Provide Learner Controls.

Another method of personalization is to provide controls to the learners that allow them to pace their own learning, review instruction and repeat practice as wanted, and focus on topics/lessons that fit their learning needs. Learner's should be given some control, in particular the ability to review or repeat segments when needed, but not necessarily full control of the learning path. For example, if an instructor is involved, the student may not have the privilege to alter the learning path, but the instructor should. Sequence the learning material, but allow learners the control to review and/or repeat the instruction as needed during practice activities, and when receiving feedback. As the learners practice, they are testing and developing their mental models. There will be times when they experience uncertainty or do not know the correct response. Other times their mental models will be challenged when they think they understand but receive
feedback that they were wrong. At these times, learners are primed to alter their mental models and learn. Providing access to the instruction and additional practice activities with feedback will allow learners to strengthen their mental models.

Provide Administrative Controls.

Incorporate administrative components to allow customization of the CAI to the needs of particular learners. For example, such controls will enable a learning manager to customize the assigned lessons or courses, learning activities, testing schedules, etc., to specific learners. The “learning manager” may be a teacher, instructor, administrator or the learners themselves. The term is used here to refer to whoever is helping to manage the learners’ progress to the learning objective. This principle suggests that CAI be designed to help the learning manager with that task by incorporating administrative controls so that the CAI can be further customized for a specific learner or set of learners. For example, LBAL allows the teacher to include some or all of the learning activities, choose the number of questions in each activity, and choose the level of mastery (80 percent or 100 percent) required. And although the LBAL program will recommend an individualized plan of study for a student, the learning manager can adapt the plan of study, if needed. In addition, a CAI would ideally incorporate assessment tools and records to evaluate and track learner progress. There are learning and administrative benefits provided by designing CAI to evaluate and track learner progress. These benefits include:

1. providing feedback to the learners,
2. the ability to adapt instruction and practice to learners' needs based on their progress,

3. informing learners of their accomplishments and progress to the learning objective, thereby removing the cognitive load of self-monitoring progress,

4. informing instructors of learner progress,

5. helping instructors identify problem areas for individual learners, as well as a group of learners, that can be addressed inside or outside of the CAI environment, and

6. providing records for reporting learner progress and achievement to all interested parties.

Principle 9: Learner-centered design

Overall, keep the CAI system design focused on the needs of the learners. Usability is a critical measure of success for all systems design, including CAI design. It focuses the design on the needs of the users. In summary, "Usability means that the people who use the product can do so quickly and easily to accomplish their own tasks" (Dumas & Redish 1994, p 4). Although, a discussion of all of the dimensions of usability is outside the scope of this research, usability is an important characteristic that should be considered in CAI design. In addition, usability testing is crucial to test that the CAI meets the needs of the intended users because in the end, only the users can decide if a system is usable (Dumas & Redish).

A CAI will have multiple users, the primary of which is the learner. Different learners will have different needs and usability is measured individually by each.
Personalization of the learning environment to the learner is one way to address these differences between learners. Other users will include the learning manager(s) and possibly administrators. Even though the needs of the learner should come first, the needs of all users should be considered in CAI design. Consequently, a user-centered approach to CAI design is recommended and existing guidelines for interface and multimedia design should be considered.

The next section describes a design methodology for CAI that codifies the proposed nine principles aforementioned.

A Methodology for CAI Design

A methodology is the physical, standardized, and structured implementation of the project life-cycle (Whitten & Bentley 1998, Hoffer et al. 1999). Successfully implementing an effective methodology provides a consistent, systematic, and repeatable approach that can help reduce project risks. The structure and deliverables of a methodology make the process manageable, a key to successful systems analysis and design (Conger 1994; Whitten & Bentley 1998).

A systems design methodology provides a step-by-step procedure that codifies and guides the design process. This section codifies a high-level methodology for the CAI systems design process. Integrating the CAI design principles described in the previous section, this methodology is a systematic procedure for designing CAI that supports learners in developing their mental models of the learning objective. This methodology assumes that the goal of the CAI will be to increase knowledge or skills, so the inclusion of instruction in the design is a given. Based on an iterative systems development
lifecycle, this methodology differs from generic systems design methodology in that it focuses specifically on CAI systems. Moreover, the methodology recognizes the importance of instructional design to the CAI design process.

In many ways, information system analysis and design parallels instructional analysis and design. Since CAI design is a specialized form of both, this methodology integrates relevant features of each. The proposed CAI design methodology follows. Analysis and design activities are identified with the associated deliverable(s) for each step. In addition, the guiding CAI design Principles are noted in parentheses where applicable. The principles are assumed to apply to all sub-items of the notation.

1. Identify and analyze the CAI learning objective.
a. Determine the knowledge and/or skills that learners need to attain.

DELIVERABLE: Statement of Learning Objective. A one-paragraph description of the state or outcome to be attained by users of the CAI.

b. Break down the learning objective into a series of logically cohesive learning tasks. (Principle 2)

DELIVERABLE: Learning Task Plan. A Decision Tree of learning tasks and sub-tasks that represents the processes by which the learner will acquire and test knowledge.

c. Determine the smallest elements of information that can be learned independently. (Principle 2)

DELIVERABLE: Skill Tree. An outline of all declarative knowledge to be conveyed by the CAI.

d. Identify logical dependencies in the elements and learning tasks. (Principle 2)

DELIVERABLE: Elaborated Learning Task Plan - A flow diagram derived from the Learning Task Plan, it now includes dependencies among sub-tasks and links of knowledge elements to learning tasks.

2. Analyze the learners – the potential CAI users. (Principles 8 & 9)

a. Identify the pertinent characteristics of the target learners that may affect their motivation or ability to learn

i. Age and background.
DELIVERABLE: Statement of Learners Background. A one to two paragraph description of the ages and background of the target learners.

ii. Expected level of prior knowledge.

DELIVERABLE: Statement of Expected Knowledge. A one-paragraph description of the expected knowledge level of the anticipated users.

iii. Abilities/disabilities.

DELIVERABLE: Learner Abilities Statement: A one-paragraph statement about whether or not users may have disabilities and the types of disabilities that are anticipated.

iv. Learning preferences.

DELIVERABLE: Learners Need Plan: A list of means and methods that highlight the learners preferred methods of learning.

v. Attitudes and motivations for achieving learning objective.

DELIVERABLE: Motivations Statement: A one-paragraph statement of potential attitudes and motivations of the learners for using the CAI and achieving the learning objective.

vi. Context of learning and using the knowledge or skills.

DELIVERABLE: Learning Context Statement. A one-paragraph description of the environment in which the learner will use the CAI and how the learner is expected to apply the knowledge gained from the CAI.

vii. Computer experience and comfort level.
DELIVERABLE: Technology Level Graph. A two-dimensional graph with the experience levels on the vertical axis and comfort levels on horizontal axis.

b. Consider possible design features to customize the CAI design for the learner characteristics, with regard to:

i. Instructional materials (Principle 2)
   1. subordinate knowledge and skills
   2. context, setting, and relative examples

ii. Instructional methods

iii. Media implemented in the CAI: text, video, audio, graphics, etc.

DELIVERABLE: Potential Design Features Matrix. The matrix lists the learner characteristics on the vertical (rows), with the materials, methods and media on the horizontal (columns). Instructional materials, methods and media that may be used to implement the CAI are entered in the relevant cells.

3. Review related research and literature regarding issues of teaching the topic/subject and of the students/learners learning in the context of the learning objective.

a. Effective materials and instructional methods.

b. Effective media

DELIVERABLE: CAI Design Features Matrix: The matrix lists the subject and learner characteristics on the vertical (rows), with the materials, methods
and media on the horizontal (columns). Instructional materials, methods and media that have been shown to be effective in CAI are entered in the relevant cells.

4. Develop instructional materials for:

a. Instruction (Principle 2)

i. Include explicit instruction of the required knowledge, whether it is factual, procedural and/or structural

ii. Sequence instructional materials to accommodate logical dependencies of elements

iii. Organize materials for learning tasks into short, logical, independent units/lessons

iv. Integrate multisensory materials to focus and expand attention (e.g., use audio to explain concepts in on-screen illustration) (Principle 7)

v. Consider developing alternate instruction materials that explain in a different way or from a different perspective for supplement or review. (Principle 6)

DELIVERABLES: First, an Instructional Data Flow Diagram that details the sets for instruction and their interdependencies. Second, Tables of Instructional Material will be created from the Flow Diagram and Skill Tree.

b. Practice activities (Principle 3)

i. Incorporate multiple, multisensory, activities that practice/test knowledge and skills taught in the instruction from different perspectives (e.g., top-
down and bottom-up; visual to aural and aural to visual; recognition and recall, etc.)

ii. Devise short, frequent, interactive activities (to intersperse with questions and immediate feedback)

iii. Have learners make on-screen choices, entries or selections, and/or manipulate on-screen variables (to test relationships) relevant to the instruction/practice objectives (Principle 1)

DELIVERABLES: Practice Activities Table: Based on the Instructional Flow Chart and Tables, practice activity tables will be developed to support the instructional materials.

c. Assessment (Principle 4)

i. Determine types of assessments to be conducted

   1. pre-assessment – test for current knowledge (Principle 8)

   2. external assessment by CAI – record responses

   3. self-assessment by learner – no response known

DELIVERABLES: Assessment Flow Chart that details the assessment process.

ii. Develop assessment tools (questions, testing methods) that reflect the learning objective and directly relate to instruction
DELIVERABLES: Assessment Tools derived from the Instructional Tables and Assessment Flow Chart.

iii. Do not test knowledge and skills that are not specific to the instruction and learning objective.

DELIVERABLE: Evaluation Matrix. A Matrix that confirms that the knowledge/skill being tested by each assessment item in the Assessment Tools is a knowledge/skills in the Instructional Tables.

d. Feedback (Principle 5)

i. Determine structure and type of feedback (content)

ii. Develop feedback responses for practice activities and assessments

iii. Structure multi-levels of feedback

DELIVERABLES: 1) Feedback Data Flow Diagram that identifies the content of each level of feedback, with the corresponding feedback trigger (e.g., third try). 2) Tables of Feedback Response Material will be created based on the Data Flow Diagram, Assessment Tools and Practice Activities Table.

5. Design the learning environment, including selecting instructional methods and media (Principle 1)

a. Select instructional methods of presenting materials

i. Choose instructional strategies for presenting instructional materials

ii. Determine if CAI will impose mastery learning based on learner analysis

iii. Design instructional process (Principles 1, 2 & 7)
DELIVERABLES: Detailed Instructional Design Process: From the
deliverables of steps 1, 2 and 3 an interdependent instructional process will
be achievable.

b. Select media to present materials within CAI, such as

i. Text (e.g., to present facts, definitions, outlines of lectures, label visual,
transcripts of audio lectures (especially useful for hearing-disabled, non-
native speakers, learners with visual preferences)

ii. Video (e.g., expert lectures, demonstrate activities or physical skills)

iii. Illustrations/graphics (e.g., visually depict concepts, relationships, or
statistics; augment lecture)

iv. Audio (e.g., explanation of visuals, aural cues,

DELIVERABLES: 1) Selection Criteria Chart and 2) Media Presentation
Matrix: First, a Section Criteria Chart will define the most appropriate
media for different types of instructional materials created in 4. Then using
this criteria, a matrix will identify the appropriate media for each item of
instructional material.

6. Design the CAI interface to present the instructional materials, such that it
facilitates: (Principles 1 & 9)
a. explicit instruction (Principle 2)

b. multisensory activities from multiple perspectives (Principles 2 & 3)

c. frequent interactive activities that require learners to process information and respond (Principle 3)

d. assessment of learner responses (Principle 4)

e. timely, multi-level, specific and directed feedback to learners, that culminates in KRE feedback (Principle 5)

f. personalization of the learning environment to the learner based on: (Principle 8)

i. pre-assessment of learner’s knowledge and skills

ii. ongoing assessment of learner’s achievement with:

iii. instructional modules/segmented video for mix-and-match of the information needed by the learner (Principle 2)

iv. insertion of learners name

and, so that the CAI interface: (Principles 7 & 8)

g. Imposes minimal intrinsic cognitive load by integrating materials/media

h. Focuses learner attention

i. Gives learners control of reviewing instruction and repeating practice activities

j. Does not impose extrinsic cognitive load

k. Instructional modules (Principle 2)
l. Does not include extracurricular activities

m. Does not split attention

n. Imposes or facilitates mastery of each topic, track student achievement, do not let student move to advanced lessons until subordinate knowledge mastered (Principle 6)

o. Follows general guidelines for system interface design (Principle 9)

DELIVERABLES: Static Interface Designs of the CAI system.

7. Design the underlying data structures required in the CAI for managing:

a. Dynamic content in interface

b. Instructional modules/lessons/units (Principles 1-5)
   i. Logical dependencies/sequence of modules
   ii. Related practice activities, assessment, and feedback
   iii. Lessons started, completed, mastered or needing review

c. Assessment (Principle 4)
   i. Test bank of the questions/items, and the unit/topic to which each relates
   ii. Creation of tests, such as random selection or ordering of questions
   iii. Tracking specific or groups of questions/items posed

If external assessment is conducted by the CAI system, also include structures for:

iv. Student achievement on specific questions/items or average performance on groups of items for specific lessons/units

v. Lessons mastered
vi. Which review activities and reassessments are needed for mastery

d. Feedback (Principle 5)

   i. Number of tries attempted/allowed for correct response

   ii. Content for different levels of feedback

   iii. Specific feedback for different incorrect responses, if any

   If the CAI system is going to monitor and manage the students’ sequence
   and progress through the CAI, data structures to manage the following will
   be needed:

   e. Tracking students’ progression through instruction (if instituted) (Principles
   1 & 8)

      i. What lessons/modules have students started?

      ii. What lessons/modules do students need to review/practice?

      iii. What practice activities should be assigned/redone?

      iv. What lessons/modules have students mastered?

   DELIVERABLES: A Decision Tree and Data Flow Diagram that are based on
data flow diagrams and tables created in previous items.

8. Design interface and system functionality for management component, some
   possibilities include (Principle 8)
a. Selection of assigned lessons
b. Selection of practice activities
c. Number of questions/items assessing each activity
d. Levels of feedback – number of tries to answer correctly
e. Mastery level (e.g., 80% or 100%)

DELIVERABLES: Final Data Flow Diagram that incorporates the Static Interface Designs of the CAI system

9. Prototype the CAI (Principle 9)

a. The interface
b. One or more instructional modules

DELIVERABLE: A working prototype of the CAI system.

10. Conduct usability testing on CAI (Principle 9)

a. Test system operation for programming bugs

DELIVERABLE: Program Issues List: From a test group’s use of the system, create a list of programming issues that need to be addressed in the redesign stage.

b. Test interface design for usability, including ease of use, ease of learning to use, cognitive load, etc. (Principle 7)

DELIVERABLES: 1) Usability Questionnaire and 2) Usability Results Report: First, A usability questionnaire for the CAI will be created to measure the attributes of interest. Then a test group using the system will
complete the questionnaire. The Result Report will report the analysis of the data from the completed questionnaires.

c. Test instructional effectiveness of CAI learning environment and materials

DELIVERABLE: Analysis of Instructional Effectiveness: First, learning appropriate outcome measures need to be identified or developed. The effectiveness of the CAI in improving performance on these outcome measures needs to be investigated and reported in the analysis.

11. Revise CAI system design (materials, methods, media, and interface) based on results of testing, in an iterative process. (Principle 9)

DELIVERABLE: A Comprehensive Matrix that analyzes the system’s strengths, weaknesses, opportunities and threats (SWOT) to determine the viability of the next iteration of the system.

That concludes this preliminary CAI design methodology. It should be noted that design considerations of bandwidth and technology accessibility are outside of the scope of this methodology and dissertation. However, the reader should be aware that it is important to consider the technological setting in which learners and other users will use the CAI. This is especially pertinent to design decisions incorporating high bandwidth media, such as video streaming. As a rule of thumb, design the CAI for the lowest common denominator in terms of the users technology platforms. This is a general concept of all types of information systems design.

The next chapter describes the case of Agent99 Trainer, a CAI tutorial instantiating much of the design principles and methodology discussed herein.
CHAPTER 7 – A CASE OF DESIGNING CAI: AGENT99 TRAINER

Agent99 Trainer (A99) is a prototype web-based CAI training system that the researcher helped to design and develop. The primary purpose of A99 is to train people to better detect deception. Since the A99 prototype CAI was designed in general accordance with the CAI design principles and methodology described in Chapter 6, A99 serves as a proof-of-concept that demonstrates the feasibility of the prescribed design principles and methodology.

Research has shown that A99 provides an effective instructional system (Cao et al. 2003a; b; Lin et al. 2003, George et al. 2003, George et al. 2004). In experiments, learners using A99 significantly improved their knowledge of deception and cues and heuristics for deception detection (George et al. 2003, George et al. 2004). In addition, learners improved their ability to detect deception in interviews presented in multiple media formats (text, audio and video) (Cao et al. 2004; Cao et al. 2003a; Lin et al. 2003). Furthermore, the results from a series of usability tests indicate that learners perceived the A99 CAI system to be a well-designed system with good usability (Cao et al. 2004). Learners rated the system to be easy to use; easy to learn to use; a satisfactory training alternative to traditional instructor-led training; and personalized. In addition, A99 was perceived to be a useful and valuable training tool that improved user satisfaction with the training experience and provided learners control of their individual learning path.

This Chapter will provide a brief description of the A99 system, and then discuss the design of the system in accordance with the prescribed methodology. In conclusion,
the research results that substantiate the viability of the prescribed design principles and methodology will be discussed.

Introduction to Agent99 Trainer CAI system

The A99 prototype is comprised of two integrated modules: Watch Lecture and View Examples with Analysis. Adapted from a module in an existing prototype system named Learning by Asking (LBA) (Zhang 2002), the Watch Lecture module delivers a lecture, but does not provide assessment or feedback capabilities. Building on this foundation, the View Examples with Analysis module was designed to deliver practice examples and analytical, explanatory feedback. A description of the operation of each of these CAI modules follows.

Watch Lecture module

The Watch Lecture module provides explicit instructions on deception cues by capturing expert lectures on digital media. In order to provide multiple representations of reality (Jonassen, 1991), we use the combination of instructor’s video, slides and transcripts of videos to form a “virtual lecture”, which simulates a real lecture in a traditional classroom training. All the learning materials in various media types (video, slides, and transcripts) are well structured and presented in a Web interface (Figure 8). Because an advantage of traditional classroom training is that it supports diverse activities and rich media simultaneously and provides an interactive and rich learning environment (Hughes 1998), the Watch Lecture module simulates a traditional classroom-learning environment by synchronizing the three cells of instructor’s video, slides and transcripts (Figure 8).
In the Watch Lecture module, each lecture (a lengthy video) is divided into topics and sub-topics (smaller clips). Navigation buttons and an outline of topics (implemented as a topics drop down menu) are provided so that learners can easily select any topic or subtopic in the lecture at any time. This provides a non-linear format for instructions and allows learners to control their learning processes.

A unique feature specifically designed for deception detection training is the association of the deception examples with the topics in the lecture in order to combine the explicit instruction and practice. Practice is implemented in the View Example module to be discussed next). This association is implemented in two ways: 1) when the lecture (instructor’s video) goes from one topic to the next one, links to the View
Example module are provided so that learners can go directly to viewing the deception examples related to the current topic, and 2) an “Examples” drop-down menu (Figure 9) allows learners to select any example to view while they are watching the lecture. (Lin et al. 2003, pp. 2658-7)

Figure 9: Watch Lecture module – Example drop-down menu
View Examples with Analysis

Besides the "explicit instruction" implemented in the Watch Lecture module, the other two critical components of deception detection training, "practice" and "feedback", are implemented in the View Examples module (Figure 10). The View Examples module in AGENT99 Trainer is designed to provide various types of real-life examples, scenarios and expert analysis that allow learners to practice and receive immediate and elaborated feedback. When viewing an example, the system allows learners to select different media tracks (audio, video, or text) and thus focus on cues in different communication channels (vocal, visual, or verbal). For instance, the learner may choose to listen to audio without video in order to focus
on the vocal cues in deception (e.g. pitch increase) and avoid the distraction of visual cues (e.g., rigid posture). Furthermore, the View Example module is designed to provide learners with opportunities for reflection, which is critical for a training environment (Barab & Duffy, 2000). Reflection is designed and implemented as follows: an example is displayed to learners without expert analysis for a pre-coded "attention span" interval (e.g., a time period of 20 seconds) that forces the trainee to think about the example for a while, and then the system will prompt and permit the learners to view the expert analysis.

Figure 11: View Examples With Analysis – Example and expert analysis displayed
The expert analysis informs the learner not only of the veracity of the example but also points out the cues used to make the judgment, thereby supporting the learner’s refinement of her or his own mental model. In addition, having the example and the expert analysis parallel to each other in one interface (see Figure 11) allows learners to review and reflect on the example in view of the expert analysis. Overall, this design provides repeatable opportunities for learners to think and reflect before and after viewing the analysis. (Lin et al. 2003, p. 2569)

Designing Agent99 Trainer

The prescribed principles and methodology of CAI design are instantiated in the design of A99. The A99 design process is described in the framework of the design methodology presented in the previous chapter.

1. Identify and analyze the CAI learning objective.
   a. Determine the knowledge and/or skills that learners need to attain

   The first step in designing A99 was identifying two primary learning objectives for the CAI: 1) improving learners knowledge of deception and its detection, as well 2) improving learners accuracy in judging the veracity of text, audio and video communications.

   The CAI would be designed to present multiple courses on deception detection to a variety of learners. The first course to be designed would be a overview course on the Cues of Deception, including general background knowledge on deception and deception detection, as well as more specific information on known cues of deception. Adopting Buller’s and Burgoon’s (1996, p205) definition, deception was
defined as “a message knowingly transmitted with the intent to foster false belief or conclusions.”

b. Break down the learning objective into a series of logically cohesive learning tasks.

An outline for the lecture was developed to present the information in a logical sequence. Cohesive topics were identified for segmenting the lecture and lecture video. For example, each behavioral category of cues described was a separate topic/learning task.

c. Determine the smallest elements of information that can be learned independently.

Each topic contained one or more elements of instruction. For the topics on behavioral categories of cues, each individual cue of deception was an element.

d. Identify logical dependencies in the elements and learning tasks.

An outline was used to organize the lecture topics in a logical manner. The definition of deception was first, then background knowledge, and the cues last. The cues of deception were organized by behavioral categories. These categories did not have logical ordering dependencies, i.e., one category was not subordinate to another. In a general way, the topics on the behavioral categories were organized to start with the easiest or most familiar/common.

2. Analyze the learners – the potential CAI users.

Simultaneously to the analysis of the CAI learning objective, an analysis of the target learners was undertaken.
a. Identify the pertinent characteristics of the target learners that may affect their motivation or ability to learn.

It was determined that the target students for the Cues of Deception course would be U.S. Air Force junior communications and information officers attending their Basic Communication and Information Officers Training (BCOT) course. The A99 CAI course on deception would be a required add-on to the information assurance block in the course. A general student profile was obtained from U.S. Air Force personnel involved in the CAI training effort, as well as a brief curriculum description for the BCOT course. A document on strategies for communications and information officers’ professional development was reviewed to get a better idea of training experiences, expectations and learning context of the target students. All of these sources provided information that aided the learner analysis.

b. Consider possible design features to customize the CAI design for the learner characteristics, with regard to instructional materials, methods, or media.

To be relative to the students, it was determined that practice activities would need to contain some examples in the military context. Since this course would be part of weeks of intensive training, the students would need strong motivation for the importance of this course to their jobs and careers. The motivation for the importance of deception detection should focus on national security threats and threats to the integrity of information.
3. Review related research and literature regarding issues of teaching the
topic/subject and of the student/learners learning in the context of the learning
objective.

Research and literature on deception, deception cues and particularly, previous
deception detection (DD) training efforts were reviewed. Instructional methods were
identified, including critical components of instruction. Previous methods for assessing
deception detection accuracy were identified and it was determined no standard veracity
tests existed. Difficulties in DD training were also discovered. (Details of the literature
reviews are in aforementioned references.)

4. Develop instructional materials for:
   a. Instruction
      i. Include explicit instruction of the required knowledge, whether it
         is factual, procedural and/or structural

         A video-streaming lecture providing explicit instruction on the cues of deception
         was created.

         ii. Sequence instructional materials to accommodate logical
             dependencies of elements

         The lecture was organized in a logical manner, based on the analysis of the learning
         objective.

         iii. Organize materials for learning tasks into short, logical,
             independent units/lessons
The lecture was segmented into topics, as identified in the analysis of the learning objective. The video for each topic was relatively short, ranging approximately from one to three minutes each. Each lecture topic was designed to be viewed independently and understood.

iv. Integrate multisensory materials to focus and expand attention, e.g., use audio to explain concepts in on-screen illustration

PowerPoint slides were created for each topic in the lecture, to augment to video. The slides provided a bulleted outline of the main concepts in the topic lecture, such as the cues, definitions of terms. Some slides also contained rudimentary illustrations.

v. Consider developing alternate instruction materials that explain in a different way or from a different perspective for supplement or review.

Some alternate instructional information was provided by expert explanations of the practice examples. This was not addressed otherwise.

b. Practice activities

The View Examples With Analysis module was designed for the express purpose of delivering practice examples and expert feedback.
i. Incorporate multiple, multisensory, activities that practice/test knowledge and skills taught in the instruction from different perspectives (e.g., top-down and bottom-up; visual to aural and aural to visual; recognition and recall, etc.)

Examples of interview communications were developed in three media formats (text – Net Chat transcripts of interviews; video with sound; and audio). In addition, the video examples could be viewed in three modes: video with sound, video only, or audio only). The examples were developed from two sources. First, the researchers culled segments of interviews from a series of experiments on interpersonal deception. These examples were real communications. Second, to provide examples with a military context, Air Force officers created and enacted examples scenarios.

ii. Devise short, frequent, interactive activities (to intersperse with questions and immediate feedback)

Multiple practice examples were offered for each lecture topic on deception cues. At the end of each short topic, a link to the relevant examples is provided on-screen. The examples were short and encouraged the learner to try to determine the veracity of the communications before viewing an expert analysis.

iii. Have learners make on-screen choices, entries or selections, and/or manipulate on-screen variables (to test relationships) relevant to the instruction/practice objectives

During the lecture, the student is provided with a Topics button and an Examples button. At anytime during the lecture, the learner can use these respective buttons to
select a lecture topic to view or view an example for a particular topic. Navigation buttons (first, previous, next, last) are also available to allow learners to navigate between topics. However, in contrast to this guideline, it is possible for a student to run the lecture (series of topics) without interacting with the screen.

c. Assessment

i. Determine types of assessments to be conducted: pre-assessment, external assessment by CAI, or self-assessment by learner.

For this iteration of the CAI, self-assessment by the learner was selected. Expert analysis of each example and scenario was provided. After viewing an example, the learner is encouraged to *Think* about the example and determine the veracity of the communication. Then, a link to the correct answer and an expert analysis of the relevant cues is provided. This allows learners to self-assess their performance and to confirm or revise their mental models based on the information in the expert analysis.

ii. Develop assessment tools (questions, testing methods) that reflect the learning objective and directly relate to instruction

As noted above, practice examples were developed for each topic.

iii. Do not test knowledge and skills that are not specific to the instruction and learning objective

Hours were spent evaluating the cues in the experimental communications. Examples were selected so that they predominantly reflected the deception cues in the lecture.

d. Feedback
As previously mentioned, the feedback consisted of expert analyses created for each of the examples. Since self-assessment was selected, the feedback was not structured into multi-levels. In addition, for this prototype the expert analysis feedback was all text. Future iterations may implement a video format.

5. Design the learning environment, including selecting instructional methods, and media

a. Select instructional methods of presenting materials

The lecture was designed to implement expository learning and multisensory learning principles. The explicit, multisensory instruction was complemented by the case-based learning as facilitated by the multisensory practice examples. In addition to the examples, multisensory learning was accomplished with a synchronized multimedia interface that presented a video-streaming lecture, an outline slide, and a text lecture transcript simultaneously. Based on the analyses of the learner and the learning objective, imposition of mastery learning was determined to be inappropriate. However, mastery of each topic was supported by providing multiple practice examples with expert analyses to help the learners test and revise their mental models for the concepts. This was implemented to a limited extent in the prototype, which contained a small, partial sample of the examples envisioned for the CAI system.

b. Select media to present materials within the CAI, such as text, video, illustrations/graphics, audio.

This selection is interdependent on the instructional methods. As previously described, the media selected includes a video-streaming lecture; slides with text and a
few illustrations; text transcripts; examples in text, audio, video only and video with sound formats; interface graphics; and text-based expert analyses.

6. Design the CAI interface to present the instructional materials, such that it facilitates:

a. the instructional materials, b. explicit instruction, and c. multisensory activities from multiple perspectives

Since A99 was designed on the LBA foundation, the A99 Watch Lecture module adapted the LBA module. As described in the description of the Watch Lecture module, the screen was divided to present the lecture (explicit instruction), lecture slides, and lecture transcript simultaneously, in a multimedia (multisensory) format. The Topic button provides an outline of the lecture, as well as a navigation tool.

d. frequent interactive activities that require learners to process information and respond

At the end of each suitable lecture topic, the student is provided a link to practice examples on that topic. The example interface encourages students to identify the veracity of the example before viewing an expert analysis.

e. assessment of learner responses

In the present version, learners self-assess. The intention is to incorporate external assessment into the CAI in future versions.

f. multi-level, specific and direct feedback to learners, that culminates in KRE feedback
Since the learner's self assess, the feedback is not multilevel. The expert analyses provide KRE feedback, identifying the correct response and explaining that in terms of the pertinent cues in the examples and why those cues are indicative of truth or deception.

g. personalization of the learning environment to the learner

The only pre-assessment of learner's knowledge and skills was in general terms as identifies in the learner analysis. Since individual learners self-assessed, learners prior skills were not assessed nor was an ongoing assessment of learner's achievement conducted. Learners were required to self-monitor the instruction and practice activities they needed for their comprehension (i.e., to develop their mental models of deception detection). However, the lecture topics and associated materials were segmented into instructional modules that allow students with prior knowledge (or not) to select individual topics and practice examples for personalized instruction that meets the needs of the individual learner.

(6. continued) and design the CAI interface to present the instructional materials so the CAI interface:

h. Imposes minimal intrinsic cognitive load by integrating materials/media

The interface integrates the video/audio lecture with slides that highlight the major points in the lecture and/or provide illustrations, as well as a lecture transcript. The slides can be viewed while listening to the lecture. Alternatively, the transcript can be read while the student listens to the lecture. This appears to be especially helpful (i.e., reduce intrinsic cognitive load) for non-native speakers of the lecture language, who may be better at reading the language than interpreting it aurally. In addition, it can be helpful to
visual learners or others with a text preference. However, for learners who instead attempt to simultaneously watch the video lecture and look at the slides and read the transcript, the interface can split attention and produce cognitive overload. One solution to this, may be to teach such learners how the interface it meant to be used, or to allow learners to customize the look of the interface for their preferences.

i. Focuses learner attention

The multimedia interface, including the video and changing slides can help focus the learners attention on the computer screen/instruction. The ability to view examples during the lecture also contributes to focusing learner attention.

j. Gives learners control of reviewing instruction and repeating practice activities

In the Watch Lecture module, the Topic button, Examples button and navigation buttons give the learners control. In the View Examples With Analysis, the learner can select to replay examples, go to related examples, view an expert analysis or return to the spot in the lecture where they left off. All of these choices give the learner control of reviewing instruction and repeating practice activities.

k. Synchronizes features

The video, slides and transcript are synchronized so that when a topic is selected the relevant slide and transcript are also presented. In addition, the expert analyses can be viewed while reading, watching, or hearing the example.

l. Does not impose extrinsic cognitive load,
The interface is designed to focus attention on the instructional content without distractions. Color or motion should focus on relevant items.

m. Instructional modules

As aforementioned, the lecture is segmented into topics and the examples are segmented to exemplify specific topics.

n. Does not include extracurricular activities

Extracurricular activities or information is not included.

o. Does not split attention

Refer to discussion at 6. h above.

p. Imposes or facilitates mastery of each topic,

If mastery imposed,

i. Tracks student achievement, and does not let student move to advanced lessons until subordinate knowledge mastered

Mastery is not imposed in this CAI, but it is facilitated with learner control and multiple practice examples for each topic. (Note: if mastery was imposed, this feature would constrain the learners ability to access advanced topics until subordinate topics were successfully mastered.)

q. Follows general guidelines for system interface design

An attempt was made to design the interface in accordance with general guidelines for interface design to promote ease of use, learnability and other usability measures. Furthermore, usability tests evaluated users' perceptions of the interface.

7. Design the underlying data structures required in the CAI for managing:
a. Dynamic content in interface

A relational database was selected. The program My SQL was selected for this purpose. The database structure was designed with multiple tables to store and manage the video segments, slides, transcripts, examples and expert analyses, all related data, and the data relationships. The tables were normalized to optimize performance.

b. Instructional modules/lessons/units, including

i. Logical dependencies in the sequence of modules

The ordering of the lecture outline in the learning objective analysis was used to order the automatic presentation of the topics in the lecture. This metadata was designed into the tables.

ii. Related practice activities, assessment, and feedback

The relationships between lecture topics, practice examples (activities) and expert analysis (feedback) were designed into the database tables. Since, assessment was indirectly implemented, data structures for assessment are not applicable here.

iii. Lessons started, completed, mastered or needing review

This rule is not applicable, other than to keep track of the current topic, the next topic and the topic (point in lecture) to return to after viewing an example. Since A99 does not impose mastery or directly assess student achievement, the remainder of the rule does not apply.

c. Assessment

i. Test bank of the questions/items, and the unit/topic to which each relates
A database table was designed to manage the practice examples and their relationship to the topics and expert analysis.

ii. Creation of tests, such as random selection or ordering of questions

Since the practice examples served as the method of indirect assessment, this functionality was not applicable.

iii. Tracking specific or groups of questions/items posed

This rule was not implemented since practice examples substituted for the questions and the numbers of the examples in the prototype were limited. However, in the future, as more examples and topics are added, it would be good to identify for the learner the topics and examples that they have viewed/completed. With self-assessment, this could be accomplished by changing the color of the link in the Topic and Examples drop down menus and/or providing a list to the learner.

d. Feedback

Refer to discussion at 7. a and b ii.

8. Design interface and system functionality for management component

This version of the prototype implemented very limited management functionality. Based on usernames and passwords, student access to courses is controlled. However, the creation of usernames and passwords and control of course access must be accomplished at the code level. An interface will need to be designed when the management functionality is expanded.

9. Prototype the CAI.
The A99 prototype was created in an iterative process, based on the CAI design just described, and results of testing.

10. Conduct usability testing on CAI prototype for or when:
   a. The user interface design
   b. One or more instructional modules are prototyped
   c. Testing the system operation and identifying programming bugs
   d. Testing the interface design for usability, including ease of use, ease of learning to use, cognitive load, etc.
   e. Testing the instructional effectiveness of CAI prototype

The A99 prototype was tested in a series of run-throughs, experiments and usability tests. All of the items listed above were included in the testing. Refer to the next section of this chapter for a brief discussion of the testing conducted.

11. Revise CAI system design (materials, methods, media, and interface) based on results of prototype testing, in an iterative process

The CAI design of the A99 prototype continues to be revised and improved based on findings from the testing.

Testing of Agent99 Trainer Prototype

The design and effectiveness of the A99 CAI prototype has been tested in a series of experiments. The corroborating evidence indicates that A99 is well-designed, usable and effective for deception detection training. The following are excerpts from published reports of the findings. More details are provided in (Cao et al. 2004; Cao et al. 2003a; b; George et al. 2004; Lin et al. 2003; George et al. 2003)
Evaluations of Agent99 Trainer

Can People Be Trained to Better Detect Deception? Instructor-led vs. Web-based Training (Cao et al. 2003a)

Cao et al (2003) reports the results of an experiment comparing the A99 web-based CAI to instructor-led instruction. The reported results follow.

Results
In the analysis, the deception detection accuracy for each judgment test was measured by the number of correct judgments divided by the total number of test cases (6 in our experiment). This measure was calculated for each subject for both pretest and posttest as the dependent variable. Two independent variables were used in this experiment: treatment (Agent99 or Lecture) and time (pre- or post-). We conducted a 2 x 2 ANOVA with repeated measures on the time factor. Results revealed a significant main effect for the time factor, $F(1, 27) = 32.29$, $p < 0.001$, eta square = 0.545. No significant main effect for the treatment factor and no significant interactions were found in this experiment (see Table 10). Therefore, the first hypothesis was supported (the training curriculum improved learners’ deception detection accuracy), and the second hypothesis was not rejected (the Agent99 group performed no differently than the lecture group, even though the detection accuracy of the Agent99 group did improve slightly more than did the lecture group). (Cao et al. 2003a, p. 605)
Table 10: Detection Accuracy Means as a Function of the treatment and time factors

<table>
<thead>
<tr>
<th>treatment</th>
<th>N</th>
<th>pre*</th>
<th>post*</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agent99</td>
<td>14</td>
<td>.4222 (.1651)</td>
<td>.6889 (.2077)</td>
<td>&lt;.001 **</td>
</tr>
<tr>
<td>Lecture</td>
<td>14</td>
<td>.4405 (.2129)</td>
<td>.6429 (.1582)</td>
<td>&lt;.001 **</td>
</tr>
</tbody>
</table>

* Numbers are means (standard deviations).

More details on the study can be obtained in (Cao et al. 2003a).

Agent99 Training: Designing a Web-based Multimedia Training System for Deception Detection Knowledge Transfer (Lin et al. 2003)

In Lin et al (2003), the following results and analysis were reported, supporting the training effectiveness and usability of A99.

Evaluation
We evaluated our system design and implementation from two perspectives: effectiveness of Agent99 Trainer on improving detection accuracy, especially compared to lecture-based form training using an experiment, and user satisfaction of system design using usability study.

Experiment and Usability Test
To test whether the system improves deception detection accuracy and whether the performance of Web-based training system was better than performance under lecture-based training. We conducted an experiment at Research I University in the Southwest. The experiment was a pretest and posttest comparison between two treatment groups: Lecture group and Agent99 group. We found that training using Agent99 Trainer significantly improved the posttest detection accuracy (pretest mean: .4222, posttest mean: .6889, p-Value < .001). We
also found that the detection accuracy in Agent99 group (pretest mean: .4222, posttest mean: .6889) was slightly better than that of the lecture group (pretest mean: .4405, posttest mean: .6429), but not significant. Refer to (Cao, et. al, 2003) for more details.

Table 11: Participants Responses in the Usability Test (Questionnaire)

<table>
<thead>
<tr>
<th>Questions</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The overall training content is interesting to me.</td>
<td>2.33</td>
</tr>
<tr>
<td>2. The video/audio quality of the lecture is satisfactory.</td>
<td>2.83</td>
</tr>
<tr>
<td>3. It is easy to learn how to use the system.</td>
<td>1.83</td>
</tr>
<tr>
<td>4. During the learning process, I think that accessing of various parts of the system or navigating through the system is easy.</td>
<td>2.33</td>
</tr>
<tr>
<td>5. The structured and synchronized multimedia content provides aid in my understanding of the subject matter.</td>
<td>2.11</td>
</tr>
<tr>
<td>6. I enjoy the self-paced control I have in the selection of what I want to access in the learning process (be capable of watching any part of the lecture and any example at any time).</td>
<td>1.78</td>
</tr>
<tr>
<td>7. The View Example and Expert Analysis module helps me better understand the content of the lecture.</td>
<td>1.67</td>
</tr>
<tr>
<td>8. The knowledge I learn from the lecture(s) helps me analyze the examples I view.</td>
<td>1.65</td>
</tr>
<tr>
<td>9. Completing the training make me feel more confident in my ability to accurately detect deception.</td>
<td>2.28</td>
</tr>
<tr>
<td>10. I am enthusiastic/genuinely interested in utilizing this format of learning again.</td>
<td>2.41</td>
</tr>
</tbody>
</table>

Furthermore, to test the subjective effectiveness of Agent99 Trainer, we conducted usability studies along with our experiment using a questionnaire. The participants filled out the questionnaire after the posttest judgment test, and only the subjects in the Agent99 group were asked to answer questions related to the usability test. In the questionnaire, we use a 7-points Likert scale to assess learners’ satisfaction level on Agent99 Trainer (1 = Completely Agree; 2 = Mostly Agree; … 7 = Completely Disagree). The results are shown below (Table 11).
The results were highly positive, justifying our system design from a subjective view. The numbers indicate that the Agent99 Trainer system was easy to use (question 1, mean was 1.83, between completely agree and mostly agree), the structure and synchronization of multimedia contents and self-based learner control was helpful (question 5 and 6), and more importantly the method of “view examples with expert analysis” and the association of explicit instructions (lecture) with practice (examples) helped the learning of deception detection (question 7 and 8). (Lin et al. 2003, pp. 2570-1)

Additional information on the study methodology and conclusions can be found in (Lin et al. 2003).

**Training to Detect Deception: An Experimental Investigation (George et al. 2004)**

George et al (2004) reports an experiment comparing four treatments: instructor-led training, A99 training, a combination of the first two, and no formal training. The results and discussion follow.

Findings

Table 2 provides the results of the knowledge tests for the control group and the combined treatment groups for all three sessions. Each knowledge test had 12 questions, and results reported indicate the number of questions answered correctly. Table 3 provides the results of the deception detection accuracy tests for the control group and the combined treatment groups for all three sessions. Each accuracy test had six examples, and the results reflect the number of examples evaluated correctly.
Hypothesis 1 predicted that trained subjects would outperform the untrained subjects (the control group) on the knowledge tests. Performance was measured by taking the difference between pretest and posttest scores within each session. Independent t-tests showed that the treatment groups differed from the control group for all three sessions (introduction: $t(113)=-8.921, p < .001$; cues: $t(113)=-4.54, p < .001$; heuristics: $t(113)=-7.536, p < .001$) For each session, the control group did not improve, while the training session groups did, lending support to Hypothesis 1.

Table 12: Means and standard deviations (in parentheses) for knowledge pretests and posttests. (Table 2)

<table>
<thead>
<tr>
<th></th>
<th>Control (N = 29)</th>
<th>Treatments (N = 86)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
</tr>
<tr>
<td>Introduction</td>
<td>5.07 (1.60)</td>
<td>5.14 (1.64)</td>
</tr>
<tr>
<td>Cues</td>
<td>4.07 (1.49)</td>
<td>4.38 (1.59)</td>
</tr>
<tr>
<td>Heuristics</td>
<td>5.41 (2.23)</td>
<td>4.93 (2.30)</td>
</tr>
</tbody>
</table>

Table 13: Means and standard deviations (in parentheses) for accuracy pretests and posttests (Table 3)

<table>
<thead>
<tr>
<th></th>
<th>Control (N = 29)</th>
<th>Treatments (N = 85)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
</tr>
<tr>
<td>Introduction</td>
<td>2.89 (1.11)</td>
<td>3.72 (1.25)</td>
</tr>
<tr>
<td>Cues</td>
<td>4.10 (1.23)</td>
<td>2.97 (0.78)</td>
</tr>
<tr>
<td>Heuristics</td>
<td>3.86 (1.22)</td>
<td>3.38 (1.37)</td>
</tr>
</tbody>
</table>

Hypothesis 2 predicted that subjects receiving the training, which included accessing the multimedia examples for practice, would outperform the untrained subjects on the detection accuracy tests. Here, performance was also measured by taking the difference between pretest and posttest scores within the session. There were no statistically significant differences between the treatment groups and the
control group on deception detection accuracy, so Hypothesis 2 was not supported by the results.

Table 4 represents the performance breakdown for both the knowledge and judgment tests for the treatment group that used the Agent99 software and other two treatment groups. Data for the lecture only and the combination lecture and software groups have been combined for this analysis.

Table 14: Means and standard deviations (in parentheses) for judgment and knowledge pretests and posttests for Session 2, comparing Agent99 to lecture and combination treatment groups. (Table 4)

<table>
<thead>
<tr>
<th></th>
<th>Agent99 (N = 26)</th>
<th>Lecture and combo (N = 59)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
</tr>
<tr>
<td>Judgment</td>
<td>4.42 (1.24)</td>
<td>3.42 (0.81)</td>
</tr>
<tr>
<td>Agent99 (N = 26)</td>
<td>Lecture and combo (N = 60)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
</tr>
<tr>
<td>Knowledge</td>
<td>5.42 (1.60)</td>
<td>7.31 (2.70)</td>
</tr>
</tbody>
</table>

Hypothesis 3 predicted that training delivered by Agent99 would be as effective as training delivered in any other mode for gaining knowledge about deception and its detection. There were no statistically significant differences between Agent99 and the other delivery modes on deception knowledge tests ($F(1,84) = 0.65$, n.s.), providing support for Hypothesis 3. Agent99 by itself seems to be capable of delivering the same material as lecture or a combination of lecture and software.

Hypothesis 4 stated that training delivered by Agent99 would be as effective as training delivered in any other mode in terms of trainees more accurately judging between deception and truthfulness. There were no statistically significant differences between Agent99 and the other delivery modes on deception detection
accuracy (F(1,83) = 1.32, n.s.), providing support for Hypothesis 4. Training through Agent99 alone leads to the same level of performance in detecting deception as does training through lecture or a combination of lecture and software.

The general trend, although not statistically significant, is toward an improvement in deception detection accuracy for the control group (an improvement of 0.48 between the pretest of the first session and the posttest of the last session) and for the combined treatment groups (an improvement of 0.28 for the same comparison). If all subjects are combined, the average improvement in deception detection performance between the pretest of the first session and the posttest of the last session is 0.333, which is statistically significant (t(113)=2.048, p < .043) (see Figure 1).

Figure 12: Deception detection accuracy scores for control vs. combined treatment groups and for the combined sample (Figure 1)

Discussion
The groups that received training improved their understanding of deception, vis-à-vis the control group, as shown by their knowledge test performance. In addition, there were no differences in deception detection accuracy between the treatment groups and the control group, indicating that while the training improved factual knowledge, it may not have improved detection ability for students, compared to those who received no training. Obviously, this is not the desired result, but we believe that the limited examples provided in the training in Agent99 Trainer and the constrained training time are possible contributing factors. These factors may have limited the effectiveness of Agent99 Trainer, since a strong advantage of a Web-based training system is its capability of providing self-paced, repeatable training with unlimited access time.

Although there were no differences between groups, participants in the study did significantly improve their detection accuracy between the first and last veracity judgment tests, overall. It may be that mere exposure to the accuracy tests improved performance, possibly through heightening subject lie bias (Feeley & Young, 1998). Although the control group did not receive explicit training, per se, they did complete the judgment tests and received response feedback immediately afterward, like the treatment groups. This could be viewed as a form of training in that it mimics the practice with feedback provided by the View Examples with Analysis. If so, the positive result may provide substantiation for the benefits of that module to deception detection training, especially since the effect was obtained with the inclusion of a very limited number of examples. In addition, although the
veracity judgment tests were piloted, the results on one test may have been adversely biased by the training. Exit comments indicated that the answers for two items on the posttest for Session 2 seemed to contradict the Session 2 training, although inspection uncovered other tell-tale cues not covered in the training. Thus, further testing and revision of the measure may be indicated.

The lack of differences among treatment conditions at least suggests that computer-based tools can deliver relevant training material without the necessity of a human instructor delivering all of the lecture content, with the added benefit of being self-paced and repeatable with time and place independence. The subtleties exposed by comparisons made within and between groups, and on both knowledge and judgment tests, illustrates the value of the training design employed in this investigation. Tests that lack pre- to posttest comparisons, control groups, or both types of knowledge gains (cognitive and judgmental) may fail to adequately discern what a given training curriculum and tool provide.

Nevertheless, the judgment accuracy rates of the training program developed and tested in this study compare favorably with other training studies, including those focusing primarily on content analysis rather than cue-based training (Landry & Brigham 1992). It would be speculative to suggest that one type of training is favorable to another without a direct comparison. (George et al. 2004)

**User Experience with Agent99 Trainer (Cao et al. 2004)**

In Cao et al (2004), the findings of a series of three usability tests on A99 prototypes are presented. The usability attributes measured included perceived ease of
use, learnability, effectiveness, perceived usefulness, and user satisfaction. Both quantitative and qualitative data were analyzed. The lessons learned and reported in this paper follow.

Lessons learned
From this evaluation, it is evident that most participants agreed that they had good experiences while using Agent99 Trainer for deception detection training. Therefore, this research demonstrates success in using a Web-based multimedia training system as a feasible replacement or supplement for traditional instructor-led, lecture-based training for deception detection training. Also, results support that the current design of Agent99 Trainer is moving in the right direction in terms of being easy to learn and easy to use. From this usability study, we obtained deep understanding of which features of Agent99 Trainer contribute to its success, as well as which features still need to be improved in the future. They are summarized below.

Strengths of Agent99 Trainer
From both the quantitative and qualitative results, the following key strengths are apparent:

- Users can easily learn to use the Agent99 Trainer system.
- In general, the system is easy to use.
- The structured and synchronized multimedia lecture in Agent99 Trainer provides users multiple channels of training (video, audio, slides and text) in a good combination (synchronized). The multimedia can provide a satisfactory alternative to a traditional instructor-led lecture for most users.
• Users can control their own learning path in Agent99 Trainer. This makes the training process more personalized, and improves users’ satisfaction with the training experiences.

• Agent99 Trainer can allow users to learn at their own pace, anytime, anywhere. This was mentioned by users, even though these studies limited the learning time.

• The use of examples and analysis in Agent99 Trainer shows again that practice and feedback is very important in deception detection training. Users’ good experiences in getting practice and feedback in training also make them feel more positive toward the entire training process and the system.

These findings are consistent with the initial expectations of this study. This also suggests that Agent99 Trainer may be more suitable for learners who are more comfortable with self-learning and learning with computers in a multimedia environment.

Improved in the Future

As reported in the qualitative data, there are still several aspects of the Agent99 Trainer system that need to be improved. Issues reported include:

• There were a few minor navigation control bugs reported in Pilot 1 and 2. These bugs and resulting navigation problems affected users’ satisfaction toward the system. However, most of these bugs were able to be fixed before the AF study. This indicates that even minor problems that affect the predictability of system operation can affect user satisfaction. Consequently, it
is important to conduct extensive system testing before implementing any study.

- The quality of the audio/video used in Agent99 Trainer needs improvement. Results showed that users' satisfaction with a multimedia training system can be affected to a great degree by the quality of the media. This problem is primarily caused by the use of old recordings for the video examples and the non-professional video production of the lectures. However, the bandwidth restriction in the Web-based environment can also cause significant problems of audio/video quality. Therefore, lessons learned here are that the use of multimedia in Web-based training needs to be adapted to a low-bandwidth situation, and the production of video lectures needs to be done professionally with an instructor looking more natural in camera shots.

- Although most users enjoy the structured and synchronized multimedia lecture, some users reported experiencing information overload from the multimedia lecture in Agent99 Trainer. The multiple channels of training in the lecture provided too much information for these users and they felt it was hard to focus on any one of the channels. We plan to solve the information overload problem in the future by changing the interface design into a user-configurable interface, in which users can create the combination of different channels they prefer. In this way, users who prefer to learn in a single channel will be able to do so.

(Cao et al. 2004, forthcoming)
Conclusion

The results of these studies indicate that A99 does indeed provide a proof-of-concept for the principles and methodology for CAI design defined in Chapter 6.
CHAPTER 8 – CONCLUSIONS

The goals of this research are two-fold. The first goal of this dissertation was to derive an empirically-based set of principles for designing CAI that improves learning by purposefully exploiting the unique capabilities information technology. The second goal of this dissertation was to codify a methodology for implementing these CAI design principles in the design process. Both goals were achieved. The proposed CAI design principles and methodology are both described in detail Chapter 6.

The principles were derived from the research approach described in Chapter 4. The approach included review of the instructional design features of existing CAI systems, as well as existing research literature in multiple disciplines.

In summary, the 9 principles for designing CAI for improving learning are:

Principle 1: Integrate instruction, practice, assessment and feedback.
Principle 2: Instruct.
Principle 3: Practice.
Principle 4: Assess.
Principle 5: Feedback
Principle 7: Focus cognitive effort.
Principle 8: Personalize CAI.
Principle 9: Learner-centered design.

As described in Chapter 7, the methodology was applied to the design and development of a prototype CAI, Agent99. Following is a summary of the design methodology:
1. Identify and analyze the CAI learning objective.

2. Analyze the learners – the potential CAI users.

3. Review related research and literature regarding issues of teaching the topic/subject and of the students/learners learning in the context of the learning objective.

4. Develop instructional materials.

5. Design the learning environment, including instructional methods and media

6. Design the CAI interface to present the instructional materials

7. Design the underlying data structures required in the CAI

8. Design interface and system functionality for management component

9. Prototype the CAI.

10. Conduct usability testing on the CAI system

11. Revise CAI system design (materials, methods, media, and interface) based on the results of testing. This is in an iterative process.

Subsequently, the effectiveness and usability of the prototype were investigated and supported by a series of experiments, field experiments and usability tests. The success of the prototype CAI design attests to the viability of the design methodology, which integrates the proposed principles. Consequently, Agent99 provides a proof-of-concept.

For the process of reviewing and comparing exiting CAI programs, a decision matrix was developed to evaluate if their design feature complied with the CAI design principles proposed. This matrix can be used for at least two purposes with regard to existing CAI systems: 1) to compare the design of multiple CAI systems, and/or 2) to evaluate the design of CAI systems based on compliance with the principles.
Implications

The CAI design principles and methodology were developed to provide guidelines that will lead to CAI systems that better support learners in achieving their learning objectives. CAI has a growing role in educational and training efforts of all types of organizations. CAI design is relevant and applicable to a broad range of instructional contexts with important and practical implications for individuals, as well as educational, business and government organizations.

At the individual level, well-designed CAI that supports learners can help individuals achieve their learning goals, in a time-efficient and cost-effective manner. At the organizational level, CAI has the potential to aid organizations in maintaining a well-trained and skilled workforce. In addition, well-designed Web-based CAI can help educational organizations reach new markets, as well as serve under-served communities that do not normally have access. Furthermore, as demonstrated by Agent99, a well-designed CAI can help the government meet their training needs, creating a better trained military force and perhaps impacting national security.

The proposed CAI design principles and methodology provide systems designers with a framework for designing CAI systems that focuses on the learner and support learning with information technology.

1. The set of twelve empirically-based principles identifies key characteristics of CAI that promote the acquisition of new knowledge. Using the principles, a CAI designer knows important characteristics to incorporate in a CAI system to support learning.
2. The methodology codifies a systematic approach for integrating the design principles into CAI systems design. Using the framework of the methodology, a systems designer has a prescription for designing CAI that promotes learning.

3. The design principles can also be used as a benchmark for CAI systems. The instructional design features of existing CAI can be evaluated to identify if CAI complies with the standards of the design principles. Such a comparison is facilitated by the evaluation matrix.

Opportunities for Future Research

The CAI design principles are not, nor are they intended to be, all inclusive. Instead, the proposed principles and methodology focus on the instructional design elements important to supporting and improving learning by helping learners develop their mental schemas. Although the principles and methodology are conceived to apply generally, they have been tested in a very limited context, thus their broader generalizability is unproven. Admittedly, this is an initial set of principles and methodology for CAI design. Yet, the demonstrated success of the Agent99 prototype provides evidence of the merits of the principles and methodology. With future research, the principles and methodology can be revised and/or extended to greater generalizability. There are many different factors to be investigated in a research program on CAI design, but it is impossible to address them all at once.

Currently, the CAI design principles and methodology are limited in scope, in several different respects. The following discusses the limitations of this research and the innumerable opportunities for future research.
Review of Existing CAI

The existing CAI systems reviewed were in a reading context. Although several programs were reviewed, only one of those, LBAL, was studied to confirm its effectiveness. In addition, the other CAI were popular titles intended for home use. Although it was not possible at the time, future research in the reading context could compare the design and effectiveness of LBAL with another reading system marketed to elementary schools, such as Waterford. One possibility would be to conduct a longitudinal study with multiple schools.

Furthermore, it would be useful to use the principles to review and evaluate existing CAI in contexts other than reading, such as mathematics, science, or numerous training contexts. Even though Agent99 is in the context of deception detection, this could provide further insight regarding the applicability of the principles and methodology to multiple contexts. Consequently, the principles and methodology could serve as a benchmark for CAI design in multiple contexts. The evaluation matrix could be revised and further developed to serve as a benchmark tool.

Field Study

The sample for this study was small, homogeneous and unbalanced. It consisted of 4th and 5th graders at a Title I elementary school in a large school district in Tucson, Arizona. Eighteen poor readers used the LBAL tutorial, while 53 participated in the control. However, the triangulation of quantitative and qualitative data bolsters the validity of the results. As mentioned above, future research on reading CAI could
compare LBAL to another school-based reading CAI, with a much larger sample of students in multiple schools.

Agent99 Prototype

In addition, the experiments and usability tests conducted on the A99 prototype tests the system in a limited context. The scope was limited in terms of

- type of class/course (deception detection)
- length of class (1 to 3 one-hour classes, not a full course)
- time and place of student access to CAI training (only during the one-hour classes), which implied:
  - limited ability for self-paced learning (only within the designated time-frame)
  - co-location with other students and instructor provided face-to-face contact and technical support when necessary
  - students did not have to make time for using the CAI, or work alone

Web-based CAI - Anytime, Anyplace

A strong advantage of Web-based training is that it can be anytime, anyplace learning that allows self-paced, repeatable training with unlimited access. Evaluating the performance of A99 in a controlled laboratory environment, under timed conditions eliminated any such benefits. The students could not use A99 on their own and each training session occurred during one-hour classroom sessions. A longitudinal field study needs to be conducted to study time and access effects.
CAI Design Methodology

The proposed methodology was not fully implemented in designing A99, so it would be useful to continue the design and development of the A99 prototype to incorporate the other aspects of the methodology and determine their effects with regard to learning and usability. One such aspect is CAI system assessment of student achievement. Adding this capability to Agent99 will open up a host of possibilities for future research, including content and structure of multilevel feedback, assessing learner mastery, tracking student needs in terms of review and practice, and reporting progress. All of these have the potential of improving learning.

Longer Courses

Over the series of experiments conducted on Agent99, the effectiveness of four training methods were compared: no instruction, in-class Agent99, in-class instructor-led, and a combination of half instructor-led with half Agent99. In all training methods, sans “no instruction”, the deception detection training was the same in all conditions and the training time was limited to class times of one-hour or less. Although this is a realistic class-time, in many instances it would be useful to deliver classes/training of a longer duration and greater content than can be conveyed in one hour. Therefore, it will also be useful to investigate the effectiveness of Agent99 for classes or courses that run over a number of weeks or for a full semester.

In this context, the CAI might deliver multiple classes as part of a course. This research could focus on many different variables. For example, the research could be designed to compare an instructor-led course to an on-line course delivered by Agent99
or the benefit of using Agent99 as a complement to an instructor-led course vs. an instructor-led course without CAI.

Other Issues

The principles for designing CAI proposed herein focus on helping learners develop their mental models with instruction, practice, assessment and feedback. There are other design issues that need to be addressed in future research.

One such issue is designing CAI for access for students and learners with disabilities. Access for learners with disabilities (equal access) is an important and complex design issue in CAI. Equal access is a very worthy goal, but it involves a whole slew of issues outside the scope of this dissertation. In addition to being a design issue, the Americans with Disabilities Act may make designing for equal access a legal issue for some organizations. (http://www.usdoj.gov/crt/ada/adahom1.htm)

Conclusions

In this dissertation, the researcher strives to positively impact the design of CAI for supporting learners and improving the learning process. Learning is a complex process and technology adds additional layers of complexity to understand. The proposed principles and methodology are a step in the right direction, but there are many, many issues to be investigated in future research. Thus, it may be said that this dissertation raises more questions than it answers. Hopefully, it has also engaged the readers and answered a few of their questions along the way.
# APPENDIX A - ACRONYMS

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A99</td>
<td>Agent99 Trainer</td>
</tr>
<tr>
<td>ADA</td>
<td>Americans with Disabilities Act</td>
</tr>
<tr>
<td>CAI</td>
<td>Computer Assisted Instruction</td>
</tr>
<tr>
<td>DRP</td>
<td>Degrees of Reading Power</td>
</tr>
<tr>
<td>GSS</td>
<td>Group Support Systems</td>
</tr>
<tr>
<td>IS</td>
<td>Information Systems</td>
</tr>
<tr>
<td>KR</td>
<td>Knowledge of Correctness of Response</td>
</tr>
<tr>
<td>KRC</td>
<td>Knowledge of Correct Response</td>
</tr>
<tr>
<td>KRE</td>
<td>Knowledge of Correct Response with an Explanation</td>
</tr>
<tr>
<td>KRH</td>
<td>Knowledge of Correctness of Response with Hints</td>
</tr>
<tr>
<td>LTM</td>
<td>Long-Term Memory</td>
</tr>
<tr>
<td>NCE</td>
<td>Normal Curve Equivalents</td>
</tr>
<tr>
<td>NIH</td>
<td>National Institute of Health</td>
</tr>
<tr>
<td>PR</td>
<td>National Percentile Ranks</td>
</tr>
<tr>
<td>TASA</td>
<td>Touchstone Applied Science Associates</td>
</tr>
<tr>
<td>WM</td>
<td>Working Memory</td>
</tr>
</tbody>
</table>
APPENDIX B - TERMS AND DEFINITIONS

The following terms are defined for purposes of this dissertation and research. These terms may be used throughout the dissertation, so they are defined here to assist the reader’s understanding.

**Cognitive Effort.**

Cognitive effort is the utilization of working memory resources by an individual to accomplish a mental task, i.e., mentally process information.

**Cognitive Load.**

Cognitive load refers to the demand placed on limited working memory resources at any particular time. What portion of working memory resources is engaged? If many demands are placed on working memory at the same time, many of the resources are engaged and the cognitive load is high. Conversely, if relatively few working memory resources are engaged, the resulting cognitive load is low. Cognitive load can be categorized as intrinsic or extrinsic, depending on the source.

**Intrinsic cognitive load**

The intrinsic cognitive load of a learning task is the cognitive load caused by the level of element interactivity in the material being learned. It is the load inherent to the task. This cannot be directly changed, although as will be explained, the intrinsic cognitive load may be indirectly altered by reducing the element interactivity over time through learning (Sweller 1999).
Extrinsic cognitive load

Extrinsic cognitive load is the cognitive load caused by sources other than the intrinsic cognitive load of a task. Extrinsic cognitive load may include demand of working memory resources from many sources, including the environment (people talking, noise, visual distractions), daydreaming, or the presentation of instructional materials. Extrinsic cognitive load can be controlled, altered or even eliminated in many cases. For example, instructional design will effect the extrinsic cognitive load imposed by a learning task depending on how information is presented and how problems and assignments are structured (Sweller 1999).

Element

An element consumes one unit of working memory. However, the content and substance of an element is not static. What constitutes an element is a dynamic of the learning process. As a schema becomes automated through learning, the automated schema becomes an element, thereby allowing multiple elements to be automated through the learning process into one element and allowing the substance of multiple elements to become a single element in working memory. “Once we accept that elements are schemas, we also must accept that what constitutes an element cannot be determined without reference to the learner, as well as the material being learned (Sweller 1999, p.28).”

Element Interactivity

Interactive elements need to be processed simultaneously to be meaningful and understood. “Element interactivity occurs when the elements of a task interact in such a
way that they cannot be understood and learned in a meaningful way in isolation. They must be understood and learned together because in isolation, they either are unintelligible or do not contribute to understanding the task (Sweller 1999, p.25).” High element interactivity is a characteristic of a difficult learning task. As the interactivity of elements increases, the learning task difficulty increases because the task requires a greater number of elements to be simultaneously processed by working memory, and therefore requires greater cognitive resources than a task with lower element interactivity.

**Learning**

For purposes herein, learning is defined as the process of developing (forming and adapting) and automating mental schemas (Sweller 1999; Schunk 2000; West et al. 1991; Roblyer et al. 1997). A behaviorist may define learning as the adaptation and adoption of behavior in response to stimulus. Learning is a change in the frequency, rate, or form of behavior and/or response occurring as a function of environmental factors (Schunk 2000). It is associations between stimuli and response, with selective reinforcement (Skinner 1968; Schunk 2000; Roblyer et al. 1997). In other words, learning modifies behavior.

In the constructivist view, each learner constructs his or her own knowledge. Learning consists of: 1) the exploration, discovery and acquisition of knowledge and skills, 2) the formation and/or adaptation of mental schema, and 3) processing information and beliefs in the context of our experiences. Willis (1995) aptly states, “...humans construct all knowledge in their minds,... learning happens when a learner constructs both mechanisms for learning and his or her own unique version of the knowledge, colored by background, experiences, and aptitudes,” (pp. 15-16). So,
learning occurs by association between cognition and beliefs of internal and external factors (Schunk 2000). It is the function of internal mental processing of information, including: acquisition, organization, construction, coding, rehearsal, retrieval, storage, and forgetting (West et al. 1991; Roblyer et al. 1997; Schunk 2000).

To learn new information, the information must be successfully stored from working memory to long-term memory and later successfully retrieved.

**Learning Task Difficulty**

The higher the level of element interactivity, the more information that must be processed in working memory at one time, hence the greater the cognitive load and the more difficult the information is to learn and understand (Sweller 1999). Difficulty in learning and understanding information is caused by the interaction between the structure of information and previously acquired schemas, (Sweller 1999, p34).

**Motivation**

Motivation is an internal, individual process that causes a person to take action or increases the likelihood that a person will take action.

**Working memory (short-term memory)**

Working memory is our immediate consciousness. Sweller (1999) states, “We are conscious of what is in working memory and not conscious of anything else (p5).” We use working memory to process information that either is obtained from the environment via our senses or that is accessed from storage in long-term memory. Processing information includes comparing contrasting combining, relating or mentally manipulating
elements in some way (Schunk 2000; Sweller 1999; West et al. 1991; Roblyer et al. 1997).

Time and capacity are the two major constraints of working memory. First, working memory is extremely limited by the time stored information persists. If not refreshed by rehearsal, information stored in working memory remains only a few seconds before it fades (Peterson & Peterson 1959). In addition, the capacity of working memory is severely limited. In his landmark paper, "The magical number seven, plus or minus two: Some limits on our capacity for processing information," Miller (1956) reveals that the human capacity for processing information is constrained by the limited capacity of working memory to contain five to nine items or elements simultaneously.

**Long-term memory**

Long-term memory allows us to store information for long periods, and possibly indefinitely. We have no direct consciousness of the information in LTM, but instead access what is stored therein through WM. "Long-term memory is not simply a repository of rote learned facts. Rather, it contains sophisticated structures that permit us to perceive, think and solve problems. Skilled intellectual performance comes from the ability to recognize appropriate circumstances and the actions required by those circumstances. This ability comes from long deliberate practice that permits the appropriate cognitive structures to be acquired and held in long-term memory (Sweller, 1999, p10)."
Larrabee Study: Student Interview Questions

Date __________
Student Name ________________  Grade _____  Teacher ____________

DIRECTIONS:
I am interested in your opinions about reading and Larrabee’s Bridge to Literacy, the reading program that you have been using in the computer lab. We will call this program the “Larrabee program” for short.

The following statements tell how you might feel about reading and the program.

I will read each statement out loud. Please decide whether the statement talks about a person who is like you or about a person who is different from you.

There are no right or wrong answers. And only I will know how you answer. I want to know how you really feel because YOUR opinion is important.

Please answer the questions in the following way:
If the statement is very different from you, choose 1 for **Strongly Disagree**.
If the statement is little different from you, choose 2 for **Disagree**.
If the statement is little like you, choose 3 for **Agree**.
If the statement is a lot like you, choose 4 for **Strongly Agree**.

Here are three examples to try.

A. I like ice cream. 1 2 3 4
B. I like to swim. 1 2 3 4
C. I like spinach. 1 2 3 4

1. Knowing how to read is NOT important. 1 2 3 4
2. I think I can be a good reader. 1 2 3 4
3. I will never be good at reading long, multi-syllable words. 1 2 3 4
4. Learning to read is very important to me. 1 2 3 4

5. I improved my reading by using the Larrabee program. 1 2 3 4
6. From the Larrabee program, I did not learn any new strategies to help me read words. 1 2 3 4
7. The Larrabee program taught me how to sound out long, multi-syllable words. 1 2 3 4
8. I can not spell any better than I could before I used the Larrabee program. 1 2 3 4
9. After using the Larrabee program, I can understand what I read better. 1 2 3 4
10. I would rather practice reading with my teacher than on the computer.  
   Why?  

   1 2 3 4

11. I like learning on the computer.  
   Why?  

   1 2 3 4

12. When working on the computer, I don’t have to worry about what the other kids think about my reading.  

   1 2 3 4

13. Is it more embarrassing to make a mistake in class or to make a mistake on the computer?  
   In Class 1 PC  
   Computer 2 Same 3  
   Why?  

   1 2 3 4

14. Working on the computer makes it harder to focus on my lessons.  
   Why?  

   1 2 3 4

15. I can concentrate better when working on the computer than I can concentrate when working by myself with my teacher.  
   Why?  

   1 2 3 4

16. When learning to read, the computer helps me concentrate better than I can concentrate in the classroom.  
   Why?  

   1 2 3 4

17. Who teaches you to read when you go to the computer reading lab?  
   Ms. Karen/Ms. Grassie 1 Mr. Larrabee 2 computer 3 other  

18. In the Larrabee program, I feel like Mr. Larrabee is my private teacher.  

   1 2 3 4

19. Learning from a cartoon character on the computer is better than learning from a real person on the computer.  
   Why?  

   1 2 3 4

20. Working with a real live teacher 1-on-1 is better than working with a teacher like Mr. Larrabee on the computer.  
   Why?  

   1 2 3 4

21. When I get an answer wrong, I like trying again before I’m given the right answer.  

   1 2 3 4

22. Doing lessons again and again until I get everything right helps me learn.  

   1 2 3 4

23. If I am wrong, I do not want to try again.  

   1 2 3 4

24. Coming back to words I missed makes me a better reader.  

   1 2 3 4

25. Being able to work as slow or as fast as I want helps me learn.  

   1 2 3 4
Larrabee Study: Student Interview Questions

26. I like that I am able to make Mr. Larrabee repeat what he says whenever I want to.
   Do you make Mr. Larrabee repeat what he says more 3, less 1 or the same 2 amount as you would ask your teacher to repeat what he/she says?
   Why is that? .................................................................
   M L S

27. When the Larrabee program was hard for me, I wanted to quit.
   .................................................................
   1 2 3 4

28. The Larrabee program challenged me to learn more.
   .................................................................
   1 2 3 4

29. If a lesson is easy for me, it is boring.
   .................................................................
   1 2 3 4

30. Working on the Larrabee program makes me feel successful.
   Why? .................................................................
   .................................................................
   1 2 3 4

31. .................................................................

32. The hints Mr. Larrabee gives when I get a word wrong are not helpful.
   Why? .................................................................
   1 2 3 4

33. When I get a word wrong, Mr. Larrabee helps me learn by saying the word again very slowly.
   .................................................................
   1 2 3 4

34. The Larrabee program does not help me understand why my answers are wrong.
   .................................................................
   1 2 3 4

35. I learn more when I find out right away whether my answers are right or wrong.
   Why? .................................................................
   .................................................................
   1 2 3 4

36. The Larrabee program helped me by teaching me how to pronounce the sounds of letters that I did not know how to say before.
   What letters did you learn? .................................................................
   .................................................................
   1 2 3 4

37. Mr. Larrabee showing me how to make the sounds of letters with my mouth and tongue was helpful to me.
   .................................................................
   1 2 3 4

38. Learning about the voiced and air (unvoiced) sounds did not help me.
   .................................................................
   1 2 3 4
Larrabee Study: Student Interview Questions

39. The Larrabee program teaches me strategies or tricks that help me know how to pronounce words.

Name 3 strategies that help you pronounce words.
1. ____________________________ 2. ____________________________ 3. ____________________________

Do you use any of these strategies? Which one is the most helpful?
- r e ats the vowel
- patrolman i
- blends
- tion, sion say shun
- vowel sound stick
- stopsign a
- rule for c
- sound it out
- tch after short vowel
- gi, ge for j
- cautious w
- policeman e
- r does not eat the vowel

40. Each lesson in the Larrabee program has many different activities. Which activities helped you learn to read? I'll read the names of each activity and you tell me whether or not it helped you learn to read.

<table>
<thead>
<tr>
<th>Activity</th>
<th>1</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word building activity</td>
<td>Y</td>
<td>N</td>
<td>A little</td>
<td>Some</td>
<td>A lot</td>
</tr>
<tr>
<td>Listen &amp; find activity</td>
<td>Y</td>
<td>N</td>
<td>A little</td>
<td>Some</td>
<td>A lot</td>
</tr>
<tr>
<td>Reading activity</td>
<td>Y</td>
<td>N</td>
<td>A little</td>
<td>Some</td>
<td>A lot</td>
</tr>
<tr>
<td>Writing activity</td>
<td>Y</td>
<td>N</td>
<td>A little</td>
<td>Some</td>
<td>A lot</td>
</tr>
<tr>
<td>Vowel sound stick</td>
<td>Y</td>
<td>N</td>
<td>A little</td>
<td>Some</td>
<td>A lot</td>
</tr>
<tr>
<td>2-syllable activity</td>
<td>Y</td>
<td>N</td>
<td>A little</td>
<td>Some</td>
<td>A lot</td>
</tr>
</tbody>
</table>

Now, rank the activities in the order that they helped you learn to read, with 1 being the activity that helped you the most.

Why did you choose __ as most helpful? _______________________________________

41. Doing many different activities for the same lesson did not help me learn the lesson better than if I had just done one activity.

42. The Larrabee program taught me how to make the right choices for spelling a word.

43. Mr. Larrabee did not teach me why words are said the way they are.

44. I did not learn why words are spelled the way they are from the Larrabee program.

45. With the strategies I have learned from the Larrabee program, I can read new words on my own.
Larrabee Study: Student Interview Questions

46. The computer is not fun to use. Why? ________________________________

47. The best thing about the Larrabee program is using the computer. Why? ________________________________

Overall assessment:

48. What would you tell a friend or classmate about the Larrabee program?

49. What would you tell your friend helped you the most?

50. What would you tell them helped you the least?

51. What would you tell your friend you like the most about the Larrabee program?

52. What would you tell your friend you like the least about the Larrabee program?
Demographics:

Now, I would like to ask you a few more questions so I know a little more about you. Then we will be done.

53. Do you speak Spanish?  
   English 1  Spanish 2  Other ________

54. What language did you learn to speak first?  
   English 1  Spanish 2  Other ________

55. What language do you speak best?  
   English 1  Spanish 2  Other ________

56. What language do you speak most at home?  
   English 1  Spanish 2  Other ________

57. What language do your parents speak most at home?  
   English 1  Spanish 2  Both 3 Other ________

58. Did the Larrabee program help you learn to speak English?  
   How? ______________________________________

   Y  N

59. Before starting the Larrabee program, I needed help with my reading.  
   1  2  3  4

Special reading programs

60. Have you ever had individual tutoring for reading before?  
   What grade were you in? ______  Who tutored you? ___________________
   Where were you tutored?  School 1  Home 2  Other ________

61. Have you ever been in other reading programs or special reading instruction?  
   What grade were you in? ______  What was the program? __________
   Where was the program?  School 1  Home 2  In class 3  Other ________

62. Have you ever used other computer programs to learn to read?  
   I was in ____ grade.
   What computer programs did you use? ____________________________
   Where did you use the computer programs?  School 1  Home 2  Other ________
REFERENCES


