Visual learning through Hypermedia

Catherine Livesay Walker
VISUAL LEARNING THROUGH HYPERMEDIA

A Project
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Education: Instructional Technology

by
Catherine Livesay Walker
June 1996
VISUAL LEARNING THROUGH HYPERMEDIA

A Project
Presented to the
Faculty of
California State University,
San Bernardino

by
Catherine Livesay Walker

June 1996
Approved by:

Dr. Susan M. Cooper, First Reader

Sylvester Robinson, Second Reader
ABSTRACT

Visual learning is one of several modalities by which individuals perceive, encode, store, and later retrieve learned information. Categorized as an information processing theory, research of visual learning provides hypotheses for the following important questions:

1. How does the human brain store information acquired from text and/or pictures?
2. How do text and pictures assist the learner in the knowledge acquisition process?
3. How can the theory of visual learning be implemented through hypermedia to assist in the knowledge acquisition process?
4. More specifically, how can hypermedia promote effective learning within the science curriculum?

Each of these points will be discussed in the literature review section of this project. Implications of the third and fourth questions will be further discussed in the project review section.

To facilitate the visual learning process, instructional materials must be geared to assist in this complex mental process. Hypermedia, with its capability to present both text and pictures in a non-linear fashion, is a very appropriate tool for this task.

To test the implementation of the visual learning theory through the use of hypermedia, this author has developed a computer-assisted instructional program. This program will be used by the CSU, San Bernardino Physical Geology students. Serving as an interactive physical geology manual, this computer-assisted program links key words to intricate illustrations and high-quality color images. This program uses these key words
and graphics to build cognitive associations (mental models) for the learner with several possible outcomes: 1) recall of correct information from short-term memory; 2) integration of the factual components into a conceptual knowledge base; and 3) application of the knowledge base to future situations relating to the geological sciences and the physical world around us.

Intense collaboration among faculty members from the Department of Physical Geology, the program illustrator/photographer, and the project chair, has resulted in this computer-assisted instructional program, titled "Virtual Geology."
ACKNOWLEDGMENTS

This project is dedicated to my grandparents, Jack and Bess Walker. Early on, my grandparents taught me that the only job worth doing was a job well done. This basic principle has influenced every part of my life. This project is a tribute to their superb guidance.

I would also like to thank my parents, Donna Walker and Leland Livesay. From my parents, I learned the meaning of morals, judgement, and determination. Without these characteristics, I would not have realized this educational goal.

A special thanks goes to my husband, David E. Neighbours. Acting as the photographer and illustrator for Virtual Geology, David’s “visuals” are the foundation of this project. I thank him for his encouragement, patience, and support throughout the completion of this project. His presence in my life illuminated the path in this endeavor.

My many thanks go to Mr. Sylvester Robertson for providing such a rich education. I appreciate the many opportunities Mr. Robertson provided that broadened my abilities and my vision. I will truly miss having Mr. Robertson as an instructor.

I also consider myself very fortunate that I have had the opportunity to work closely with my first reader, Dr. Susan M. Cooper. Her timely influence, three years ago, changed my life forever. Her encouragement led me to join this M.A. program. Throughout the duration of this project, Dr. Cooper has given freely of her time. She has read every single screen in the Virtual Geology application and provided valuable feedback. Above all, through Dr. Cooper’s guidance, I have realized my aspiration to
become an educator. As an educator, I now have the opportunity to provide encouragement and support to others as they seek to realize their own goals.

I would also like to express my appreciation to the Associated Students Incorporated Research and Travel Fund Committee. The funding I received from this committee assisted in the development of the *Virtual Geology* application.
TABLE OF CONTENTS

ABSTRACT .................................................................................. iii

ACKNOWLEDGMENTS ................................................................. v

LIST OF TABLES ........................................................................ ix

LIST OF ILLUSTRATIONS .......................................................... x

TERMINOLOGY ........................................................................... xi

CHAPTER I: INTRODUCTION ......................................................... 1

CHAPTER II: LITERATURE REVIEW

Overview .................................................................................... 10

B.F. Skinner and Robert Gagné:
A Comparative Look at Behaviorist Theory
vs. Cognitive Theory ................................................................. 11

The Concept of Visual Learning:
Neurological Theories of How the Human Brain
Stores Information Acquired from Text and/or Images .......... 23

The Concept of Visual Learning:
External Theories of How Text and Images Assist
the Learner in the Knowledge Acquisition Process ............... 33

Computer-Assisted Instruction:
Advantages and Disadvantages, Types, and Tools ................. 62

Conclusion:
Effective Instructional Design .................................................. 77

CHAPTER III: PROBLEMS, GOALS, AND IMPLEMENTATION .......... 80

CHAPTER IV: PROJECT REVIEW

Background:
The Creation of Virtual Geology .............................................. 83
LIST OF TABLES

Table 1: Age Range ........................................ 114
Table 2: Gender ........................................... 114
Table 3: Academic Major ................................. 114
Table 4: Previous Computer Experience ........... 115
Table 5: Type of Computer Experience .......... 115
Table 6: Sections of the Program Used .......... 115
Table 7: Time of Day the Program was Used ... 116
Table 8: Length of Time the Program was Used 116
Table 9: Age Range by Gender ....................... 117
Table 10: Age Range by Major ....................... 118
Table 11: Major by Gender .............................. 118
Table 12: Computer Experience by Gender .... 119
Table 13: Time Spent Using the Program by Gender 120
LIST OF ILLUSTRATIONS

Figure 1: Three Theories of Neurological Function ........................................ 4

Figure 2: Dual Coding .................................................................................... 25

Figure 3: Single Coding ................................................................................ 28

Figure 4: Dual Coding/Single Coding Synthesis ............................................. 30

Figure 5: Three Processes for Meaningful Learning ...................................... 36

Figure 6: Example of Stated Learning Objective ............................................ 38

Figure 7: Example of Internal Connection using a Mnemonic Device .......... 39

Figure 8: Example of External Connection using Previous Information ........ 41

Figure 9: Example of Illustrated Image .......................................................... 43

Figure 10: Example of Synchronized Instruction ........................................... 45

Figure 11: Example of a Representational Image .......................................... 48

Figure 12 (A, B, and C): Example of an Organizational Image ...................... 49

Figure 13: Example of an Interpretational Image .......................................... 53

Figure 14 (A, B, and C): Example of a Transformational Image .................... 55

Figure 15: Virtual Geology Storyboard ......................................................... 91

Figure 16: Virtual Geology Main Menu (Storyboard) .................................... 92

Figure 17: Virtual Geology Topographic Maps Menu (Storyboard) ............. 93

Figure 18: Virtual Geology Learning Objective/Assistance Statement .......... 94

Figure 19: Virtual Geology Choose A Topic Menu ...................................... 96

Figure 20: Virtual Geology Topographic Maps Pull-Down Menu ............... 97

Figure 21: Final Storyboard for Virtual Geology .......................................... 104
TERMINOLOGY

Behaviorism: The study of behavior in response to events taking place in one's environment (Kemp & Smellie, 1989).

CD-ROM: A storage device that uses compact discs (CDS) to store data. Although a large amount of data can be stored on these disks, they're "Read Only Memory" disk drives. Data cannot be saved on the disc, it can only be read (Paulissen & Frater, 1992).

Clip art: A clip art collection may contain a random assortment of images, sounds, or video. It could also be a series of images, sounds, or video related to a specific topic (Osborne, 1994).

Cognitive strategy: An activity undertaken to facilitate understanding, such as comparing, describing, or summarizing (Bell-Gredler, 1992).

Computer-assisted instruction: The use of computer-based materials to assist the learner in understanding ideas and in acquiring information too complex for verbal explanation alone (Kemp & Smellie, 1989).

Digitize: A process that converts image, sound, or video into a binary (or computer) format (Paulissen & Frater, 1992).

Dual coding: The position that maintains that the information stored in long-term memory may be in either visual or verbal form (Bell-Gredler, 1992).

Encoding: The process of transforming stimuli so that the information may be stored in long-term memory and retrieved for later use (Bell-Gredler, 1992).

Geological Sciences: The science that deals with the study of the planet Earth—the materials of which it is made, the processes that act to change these materials from one form to another, and the history recorded by these materials; the forces acting to deform the outer layers of the Earth and create ocean basins and continents; the processes that modify the Earth's surface; the application of geologic knowledge to the search for useful materials and the understanding of the relationship of geologic processes to people (Skinner & Porter, 1989).

Hard Drive: A rigid, usually non-removable disk. Hard drives store much more data and access it much more quickly than floppy diskettes (Naiman, Dun, McCallister, & Kadyk, 1993).
Megabyte (MB): Storage capacity totaling 1,024 Kilobytes; usually abbreviated simply as MB (Paulissen & Frater, 1992).

Hypermedia: A extension of text-to-text links (hypertext) to non-linear links between text and audio, text and images, text and video, images and graphics, and so on (Reushle, 1995).

Hypertext: A specific form of data retrieval that takes advantage of the random access capabilities of computers to overcome the strictly sequential medium of printed material. Typically, hypertext is based on key words that provide links to other material (Harris, J., Murden, C. & Webster, L. 1993).

Information processing theory: The mental processes whereby human beings perceive, organize, and remember the vast amounts of information received daily (Kemp & Smellie, 1989).

Long-term memory: Information in an inactive state that, unless forgotten, may be recalled for future use (Bell-Gredler, 1986).

Mental models: A form of representation whereby the learner constructs an internal “picture” of external information or situations (Mandl & Levin, 1989).

Multimedia: A combination of hardware, software, and storage technologies incorporated to provide a multisensory information environment (Galbreath, 1992).

Operant conditioning: The process of modifying a subject’s behavior through the reinforcement of appropriate responses in the presence of the appropriate stimuli (Bell-Gredler, 1992).

Physical Geology: A science that deals with the history of the earth and its life especially as recorded in rocks (Skinner & Porter, 1989).

Proposition: A single, uniform, abstract type of representation (Kieras (1978).

Representation: Knowledge that is stored in a unique memory system in a propositional format independently of whether it was decoded as linguistic or visual information (Molitor, Ballstaedt, & Mandl, in Mandl & Levin, 1989).

Single coding: A single form of representation for both text and images in long-term memory (Richardson, 1980).

Spatial Ability: Ability for subjects to carry out tasks which feasibly can only be carried out by manipulating some pictorial representation. (Richardson, 1980)
**Storyboard**: A storyboard describes how a user will interact with and navigate through the content of a project, as well as the parameters of the project, the artwork, and the programming (Vaughan, 1994).

**Video Clip**: A sequence of graphic scenes (frames), rapidly played back to give the viewer a sense of motion or action (Vaughan, 1994).

**Visual learning theory**: A means by which a learner builds up a specific knowledge structure based on the information obtained from texts and images (Mandl & Levin, 1989).
CHAPTER I: INTRODUCTION

The importance of pictographic images in communication and learning can be seen as far back as 4000 B.C. Sumerian writings, inscribed on clay tablets showing approximately 2,000 signs and symbols, were found in the ancient city of Babylon. In comparatively modern time, it is recorded that in 1658, Johann Amos Comenius made the first educational link between text and images in his Latin text-book, "Orbis sensualium pictus." In this book, Comenius introduced 4,000 words, each illustrated with a wood carving. "Comenius not only regarded the pictures as a mnemonic aid, but he also substantiated their use in the bounds of a holistic pedagogy" (Molitor, Ballsteadt, & Mandl, in Mandl & Levin, 1989, p. 5).

Today, quantified learning outcomes are the measures of effectiveness for some educational systems. Consequently, instructional materials are chosen which contribute effectively to the target goals of these educational systems. Visual learning theory indicates that the integration of text and images is crucial to the learning process, and the study of visual learning can contribute to the design of effective learning materials. Molitor, Ballsteadt, and Mandl (in Mandl & Levin, 1989, p. 13) describe acquiring knowledge from text and pictures as an:

"Interactive process between learners and the teaching materials. Corresponding to their prior knowledge and to their cognitive strategies, learners build up a specific knowledge structure based on the information obtained from texts and images."

This process of "building" the knowledge structure is the core of the visual learning theory (a sub-set of information-processing theory).
"The dominant cognitive model at present is the information-processing model of cognition" (Bell-Gredler, 1986, p. 68). The visual learning theory (a sub-set of this theory) supports the integration of text and images as a crucial component of the learning process. The study and application of visual learning can contribute to the design of effective learning materials. To fully realize the significance of visual learning on the development of computer-assisted instruction, a historical understanding of learning theory is important. From approximately 1950 to present, many theoretical perspectives gained prominence. Bell-Gredler (1992) describes two major theories and their relevance to teaching and learning: B.F. Skinner's operant conditioning theory and Robert Gagné's interactionist approach. B.F. Skinner's operant conditioning theory dealt mainly with behavioral modification through the use of reinforcers for appropriate behavior. In a move toward a cognitive approach to learning, Gagné's interactionist approach called for integration of two factors: the learner's cognitive processes and stimulation from the environment. The two factors interact in the acquisition of different kinds of knowledge.

The practical application of the visual learning theory provides educators a key mechanism for understanding how individuals perceive, encode, store, and later retrieve learned information. "Illustrations have become an indispensable component in teaching material and other expository texts" (Molitor, Ballsteadt, & Mandl, in Mandl & Levin, 1989, p. 6). In practical application, the visual learning theory can provide educators with guidelines for constructing materials to achieve their stated learning objectives.

Cognitive-psychological research related to the study of visual learning shows that there are many different approaches to this theory. The two approaches selected for
discussion in this study are related to the neurological functioning of the brain and the external application of this theory. The section covering the neurological functioning of the brain is concerned mainly with how text and visual information is stored and retrieved.

The second approach to visual learning encompasses the external application. This includes how the learner interacts with text and images to facilitate the building of knowledge structures.

Regarding neurological functioning, cognitive theorists study how the human brain stores information acquired from text and/or images. From this group, Paivio, Pylyshyn, and Kosslyn emerge, each supporting one of three possible theories on how the brain processes and stores information (Figure 1). Paivio (1986; Clark & Paivio, 1991) originated the theory of dual coding. In the realm of this theory, he concludes that text and images are processed differently. His assumption is that there are two modality-specific processing systems: one for text and one for images. Pylyshyn (1981, 1986) argues a different position. He theorizes that there is one uniform processing system, or single code approach as to how the brain processes and stores text and images. Kosslyn (1981) supports a combined theory. His initial two-stage processing approach, one for text and one for images, echoes Paivio’s theory. However, the final stage, of single representation for text and images, resembles Pylyshyn’s theory.

The theory of mental models offers a means of mediation among the above presented theories of knowledge acquisition. Theoretically, mental models are built around representations, or the internalization of concrete experiences related to some aspect of reality. A mental model is a form of representation whereby the learner
Three Theories of Neurological Function

Central Processing

Approach I

Approach II

Approach III

Peripheral Processing

Text

Pictures

Text

Pictures

Text

Pictures

Two Modality-Specific Processing Systems (Dual Coding)

Two-Stage Processing System (Dual Coding/Single Coding Synthesis)

Unified Processing System (Single Coding)

Figure 1

(Adapted from Mandl & Levin, 1989)
constructs an internal “picture” of external information or situations (Molitor, Ballstaedt, & Mandl, in Mandl & Levin, 1989). Mental models allow the learner to later draw on the information stored to complete tasks and solve problems. In terms of the previously described theoretical approaches (dual coding, single coding, and the synthesis), mental models only exclude the single code approach. In the single code approach, the final representation of text and images requires an integration of the two factors (text and images), or implies some sort of dependency. Mental models can be built from either text, images, or a combination of the two. Each theory: dual coding, single coding, the synthesis of these two, as well as the mental model theory will be discussed in chapter two.

Within the second approach selected for discussion, the theorists are concerned primarily with the external application of the visual learning theory. Richard E. Mayer is a leading cognitive theorist who has conducted extensive research on the educational value of text and images. Through his research, Mayer (in Mayer & Sims, 1994) addresses how the integration of text and images can assist the learner in the knowledge acquisition process. His research results have a direct bearing on the premise for this study: how can hypermedia promote effective learning within a science curriculum, specifically the study of geological sciences? Examples from the Virtual Geology application will be used to demonstrate interpretations (and implementation) of his research results. Levin (in Levin, Carney, & Levin, 1994), addresses five main functions of images corresponding to knowledge acquisition. These functions include decoration, representation, organization, interpretation, and transformation. A meta-analysis of research related to the use of text
and images was performed by Levin, Anglin, and Carney (1987). Findings from this analysis will be discussed in chapter two, showing how images influence retention and comprehension. Also addressed in chapter two is a discussion of how different learning styles may affect one's ability to implement visual imagery skills. Some researchers, such as J.A. Slee (in Fleming & Hutton, 1983) indicate that learners can be rated based on their ability to produce mental images. Terms such as "high imagers" and "low imagers" are a product of this study; these classifications are related to different learning styles. Since one teaching strategy may not be effective for every different learning style, circumstances that qualify the use of visual learning will also be discussed.

While cognitive theory does influence today's learning environment, it is the theory of behaviorism that continues to have a significant impact on the development of educational software. The "first real learning technology, programmed instruction, was one of the most effective manifestations of behaviorism" (Jonassen, 1990, p. 33). It is difficult to depart from a theory which so strongly supports the concept of a controlled learning environment and measurable behavioral changes. But many researchers agree that "behaviorist learning theory cannot explain the complexities of human learning, especially knowledge-based learning" (Jonassen, 1990, p. 33). This idea, coupled with the development of advanced computer systems, brought about the resurgence of cognitive theory. During the late 1970's, the study of cognitive processes began taking precedence over behaviorist thought. Computer systems, with their capabilities for receiving, storing, and retrieving information, piqued theorists' interest with their metaphor of human mental processes.
The 1980's were well-known for the introduction of personal computers into homes and schools. During this period, educators had several brands and models to choose from, including the Apple II, Commodore 64, and Radio Shack's TRS-80. However, the lack of well-designed educational software was a crucial issue. In these early years, educators used a programming language called “BASIC” (Beginners All-purpose Symbolic Instruction Code) to develop simple programs that could be used in the classroom. Unfortunately, programming languages at that time did not have the capabilities that modern development languages have. As a result, most application programs that were developed focused only on behavioral skills (stimulus/response). The behavioristic model only promotes the encoding of information in a linear fashion. In cognitive terms, these stimulus/response programs did not generate higher level thinking skills. The need for educational software that promotes “higher level” thinking skills still exists today. To develop those higher level skills within students, the design of computer-assisted instruction must move away from the behavioristic model to a cognitive approach that promotes complex networked associations (Vazquez-Abad & Winer, 1992).

Complex networked associations can be developed through the implementation of the visual learning theory. Modern tools for developing computer-assisted instructional applications are sophisticated and flexible. They allow the creator to design and develop complex hypertext applications. Hypertext applications enable the linking of related data throughout a database to create the sort of “non-linear thinking pathways that characterize so much of our learning” (Harris, Murden & Webster, 1993, p. 118). “Hypertext should improve learning because it focuses attention on the relationships between ideas rather
than isolated facts. The associations provided by links in a hypertext database should facilitate remembering, concept formation, and understanding” (Kearsley, 1988, p. 23).

By combining hypertext programming with the theory of visual learning, we can build powerful instruments for teaching and learning. The ability to recognize images and objects may seem to be a fundamental, internal process. However, the development of correct and accurate mental models depends upon the scope and range of visual information presented to the learner. “Graphic representations are important because they help the learner to comprehend, summarize, and synthesize complex ideas in ways that, in many instances, surpass verbal statements” (Van Patten, Chao, & Reigeluth, 1986, p. 437). Mental models, which are the learner’s fundamental understanding of text and/or images, can be developed by applying hypertext programming and visual learning theory to sets of discipline-specific information.

The goal of this M.A. project is to show that hypermedia can be used to promote effective learning within the subject area of geological sciences. Reushle (1995) describes hypermedia as the extension of text-to-text links (hypertext) to non-linear links between two different forms of information, such as text and images. To test the implementation of the visual learning theory through the use of hypermedia, this author has developed a computer-assisted instructional program. This program will be used by the CSU, San Bernardino Physical Geology students. Serving as an interactive lab manual for physical geology, this computer-assisted instructional program links key words to intricate illustrations and high-quality color images. This program uses these key words and graphics to build cognitive associations (or mental models) for the learner with several
possible outcomes: 1) recall of correct information from short-term memory; 2) integration of the factual components into a conceptual knowledge base; 3) application of the knowledge base to future situations relating to the geological sciences and the physical world around us.
CHAPTER II: LITERATURE REVIEW

Overview

"The two major media for communicating scientific information to students are words and pictures" (Mayer & Gallini, 1990, p. 715). The computer-assisted instructional program, Virtual Geology, was designed and developed by implementing the theory of visual learning through the use of hypermedia. Serving as an interactive physical geology manual, this computer-assisted program links key words to intricate illustrations and high-quality color images. This program uses these key words and graphics to build cognitive associations for the learner. The purpose of this literature review is to provide a historical understanding of learning theory (both behavioral and cognitive), to explain the significance of the visual learning theory, its relationship to other learning theories (both behavioral and cognitive), and its impact on the development of computer-assisted instruction.

To understand the conceptual basis of the visual learning theory, it is beneficial to look at its historical precedents. Two theories have been selected for discussion: B.F. Skinner's operant conditioning theory and Robert Gagné's interactionist approach. The basis of these two theories, both behavioral and cognitive, and their significance to teaching and learning will be shown.

The discussion of visual learning theory has been separated into two sections: 1) the neurological functioning of the brain and 2) the external application of this learning theory. Theories of neurological functioning are discussed to explain how the human brain stores text and images. The external application of the visual learning theory
addresses how text and images can be used to assist the learner in the knowledge acquisition process. Within each section, the contributions of various theorists will be explained.

Following the discussion of the visual learning theory, the literature review will show how different theories (including visual learning) have affected the development and implementation of computer-assisted instruction. A retrospective will be offered, detailing advantages and disadvantages, types, and tools for creating computer-assisted instructional materials.

The final section considers effective instructional design utilizing the conceptual understanding of the three learning theories presented: B.F. Skinner’s operant conditioning theory, Robert Gagne’s interactionist cognitive theory, and the information processing theory. Madhumita and Kumar (1995) state that these theories are “neither mutually exclusive or mutually complementary. They may, however, overlap” (p. 58). Kemp and Smellie (1989) have examined these theories (and others) and have developed a list of ten “areas of agreement and similar emphasis” (p. 19). Each of these ten considerations will be discussed. Ertmer and Newby (1993) stress the importance of all three theories, and advocate that instructional designers be well-versed in each.


To fully realize the significance of visual learning on the development of computer-assisted instruction, a historical understanding of learning theory is important. From approximately 1950 to the present, many theoretical perspectives gained prominence.
Bell-Gredler (1992) describes two major theories and their relevance to teaching and learning. These two theories are B.F. Skinner's operant conditioning theory and Robert Gagné's cognitive approach. In the sections below, each theory will be discussed in greater detail.

**B.F. Skinner's Operant Conditioning Theory**

The field of psychology has been traditionally divided by two basic types of associative learning: classical conditioning and instrumental conditioning (Bower & Hilgard, 1981). Classical conditioning refers to "learning that involves the co-occurrence of environmental events" (Proctor & Weeks, 1990, p. 7). Ivan P. Pavlov is credited for his well-known classical conditioning work involving "reflexive responses to stimuli that previously did not elicit responses" (Proctor & Weeks, 1990, p. 8). For example, Pavlov found that an unconditioned, "reflexive salivary response by a dog to meat powder could be conditioned to occur when a sound was presented. Conditioning took place when the sound occurred immediately before presentation of the meat powder. After regular pairing in this manner, the sound stimulus alone came to elicit the salivary response" (Proctor & Weeks, 1990, p. 8).

In contrast, instrumental conditioning states that "the organism's own behavior is crucial in producing an environmental consequence" (Proctor & Weeks, 1990, p. 7). The early work on instrumental conditioning was performed by Edward P. Thorndike. Thorndike's work documented the role of behavioral consequences in learning (Proctor & Weeks, 1990). Thorndike felt that "for most behavior, there was no triggering stimulus that automatically produced behavior, but that behavior was influenced primarily by
expected consequences of behavior. In other words, acts that have favorable consequences will recur" (Cosgrove, 1982, p. 25). Thorndike termed this behavior the "law of effect" (Sagal, 1981, p. 20).

B.F. Skinner has employed Thorndike's research as a basis for his own theoretical studies. Within Skinner's system, instrumental conditioning is re-named "operant conditioning" (Proctor & Weeks, 1991, p. 9). Operant conditioning defined means that "when a bit of behavior has the kind of consequence called reinforcing, it is more likely to occur again" (Skinner, 1974, p. 46). According to Skinner (1974, p. 46), "A positive reinforcer strengthens any behavior that produces it, and a negative reinforcer strengthens any behavior that reduces or terminates it."

To test the theory of operant conditioning, Skinner developed a device known as the "problem box" (Skinner, 1978, p. 115). In current educational psychology, this box is commonly referred as the "Skinner box" (Proctor & Weeks, 1990, p. 11). The classic example of operant conditioning is that of a rat being placed in the testing device (problem box/Skinner's box). Whenever the animal depressed the lever, a pellet of food (positive reinforcement) was delivered (Skinner, 1978). Simply stated, "If a hungry rat is reinforced with food pellets when it presses a bar in its cage, bar pressing behavior will increase" (Cosgrove, 1982, p. 35). Skinner's learning model is very simple: Response→Reinforcement. "Thus, to ensure that learning occurs, you must ensure that the correct response is followed by positive reinforcement" (Chambers & Sprecher, 1983, p. 92).
"The principles of operant conditioning were developed in the experimental laboratory in the late 1930's. In the early 1950's, Skinner turned his attention to the classroom application of his methodology" (Bell-Gredler, 1986, p. 92). Skinner recommended that the theory of operant conditioning be applied to the development of programs that would strengthen students' verbal responses to school subjects. These programs were implemented through the use of a mechanical device referred to as a teaching machine (Skinner, 1953). According to Skinner, his teaching machine was "a mechanical anticipation of the computer" (1989, p. 92). Within the field of mathematics, the "teaching machine presented a problem in arithmetic, which the student solved by moving figures into place. The machine sensed the solution and, if it was correct, led the student on to the next problem" (Skinner, 1989, p. 92).

Skinner's teaching machine is one of the first examples of programmed learning based on the response/reinforcement model. Skinner's work has served as a basis for instructional design strategies in the development of computer-assisted instructional courseware (Chambers & Sprecher, 1983). Specifically, Skinner's views are directly applicable to the drill and practice and tutorial forms of computer-assisted instruction. Chambers and Sprecher (1983) illustrate how the Skinner model of programmed instruction is directly applicable to the design of computer-assisted instruction in the following manner: 1) provide a clear learning objective, 2) provide a series of information, questions, and answer screens that increase in difficulty and that frequently retest the same facts in different ways, 3) require a response on each screen, 4) provide immediate feedback for each answer, 5) arrange the material and questions in such a manner that a
correct response is likely to occur, 6) permit the students to proceed at their own pace, and 7) provide ample backup reinforcement for effective progress. Skinner stresses the importance of the student as an active learner who controls the learning situation (Chambers & Sprecher, 1983).

All areas of human knowledge are grounded in sets of basic facts. Skinner’s theories address the mechanisms and abilities to acquire and recall those facts. In implementing Skinner’s programmed instructional model through the use of a computer, this method has shown to be an “effective drillmaster in promoting associative learning” (Dennis & Kansky, 1984, p. 15). In general, behavioral concepts emphasize the effects of external forces and appear to have more applicability in drill and practice application, which emphasizes rote memory. However, many researchers agree that “behaviorist learning theory cannot explain the complexities of human learning, especially knowledge-based learning” (Jonassen, 1990, p. 33).

In direct contrast to the behaviorist approach, cognitive theory concepts “emphasize the effects of internal forces and appear to have greater applicability in advanced tutorial and simulation applications” (Chambers & Sprecher, 1983, p. 148). New developments in computer technology and application-development software promoted a change from the typical drill and practice applications (primarily seen as behavioral learning) to use of tutorial applications (primarily seen as cognitive learning). To understand this change, it is important to provide a counter balance to Skinner’s operant conditioning theory. Jean Piaget’s theory of development focuses on the formation of human intelligence, and provides a sound basis for any further discussion of
cognitive theory. Gagné's cognitive approach is discussed to show an alternative view to behaviorist thought.

**Jean Piaget: A Prelude to Gagné**

Piaget's work describes the development of intelligence through hierarchical reorganization and integration of cognitive structures ("schemata"). "Schemata (the plural of schema) are cognitive or mental structures by which individuals intellectually adapt to and organize the environment" (Wadsworth, 1984, p. 10). With human mental development, this process of adaptation and change occurs in all persons in the same sequence and roughly the same chronological pattern. In Piaget's cognitive-development theory, four broad stages of development identify the "qualitative differences in modes of reasoning from infancy to adulthood" (Bell-Gredler, 1986, p. 204). Piaget (1977) summarizes these four stages of cognitive development:

1) Sensorimotor (birth to 1 ½ to 2 years of age): presymbolic and preverbal;
2) Preoperational (2-3 to 7-8 years of age): partial logical thought begins;
3) Concrete operational (7-8 to 12-14 years of age): logical thoughts are linked to concrete objects; and
4) Formal operational (older than 14): ability to deal logically with multifactor situations.

Bell-Gredler (1986, p. 191) states that, "The work of Piaget places the issue of the nature of knowledge at the forefront of any consideration of human mental activity."

Skinner's operant conditioning theory overlooks the thought process, and attempts to explain knowledge as a strict process of behavioral conditioning. In contrast, cognitive theorists, such as Robert Gagné, accept the presence of knowledge, and work toward
explaining the mental activities involved in the knowledge acquisition process (Bell-Gredler, 1992).

Gagné’s Cognitive Approach

"Cognitive models evolved primarily as a result of the dissatisfaction with the limited concerns and understanding of complex processes provided by behaviorist theory" (Chambers & Sprecher, 1983, p. 98). Robert Gagné is a former follower of Skinner and the behaviorist model. In developing educational materials, Gagné supports Skinner’s “small-step” approach to learning. Gagné also promotes the use of positive reinforcement offered to the learner in a repetitive manner (Chambers & Sprecher, 1983). However, Gagné feels that behaviorist approach only works in a limited setting, such as a controllable instructional event (Gagné, Briggs, & Wager, 1992). For Gagné, instruction must take into account a whole set of factors that influence learning, collectively known as the “five categories of learning outcomes” (Gagné, 1985, p. 51).

From Gagné’s perspective, learning is a complex, cumulative process. This cumulative process consists of five categories of learning, each with their associated conditions of learning (Gagné, 1985). Gagné’s five categories and associated conditions are:

1) Intellectual skills: building concepts, learning rules and principles, and problem solving;
2) Verbal information: ability to remember facts, names, dates, and definitions;
3) Cognitive strategies: ability to think in an organized manner Using a variety of skills;
4) Motor skills: ability to perform physically to accomplish tasks; and
5) Attitudes: development of individual beliefs and behaviors.
For Gagne, these five categories of learning are accomplished through the sequential completion of a nine step process. Bell-Gredler (1992) describes these nine steps:

1) Attending: gaining the attention of the learner by providing some stimulus;
2) Expectancy: informing the learner of the expected outcome;
3) Retrieval: proving associations to previously learned material;
4) Selective perception of stimulus features: identifying the most important material;
5) Semantic encoding: Making long-term memory connections;
6) Retrieval and responding: Engaging the learning in an active mode;
7) Reinforcement: providing appropriate feedback that ensures the learner;
8) Cueing retrieval: providing additional information to the learning for further study; and
9) Generalizing: providing an environment that enhances the learner’s ability to transfer the learned information to new situations.

“Gagné’s most significant contribution, however, relates to his application of cognitive learning theory to the task of designing computer-assisted instructional modules” (Chamber & Sprecher, 1983, p. 100). His concern with gaining the student’s attention and developing expectancies represent “one of the first published attempts to introduce motivation into what has formerly been a fairly rigid concern with simple response and reinforcement” (Chamber & Sprecher, 1983, p. 100).

For Gagné, “instruction” differs from the concept of “teaching.” Instruction is described as a human undertaking whose purpose is to help people learn (Gagné & Briggs, 1979). Instruction encompasses all aspects of the learning activity, including that of teaching, and can be delivered by a variety of mediums, including the use of an interactive computer application.

Of the five categories of learning (intellectual skills, verbal information, cognitive strategies, motor skills, and attitudes), Gagné considers intellectual skills to be of “central
importance to school learning” (Gagné, Briggs, & Wager, 1992, p. 53). Bell-Gredler (1986, p. 133) states, “The content of curriculum is for the most part represented by the learning of information and the acquisition of intellectual skills.” Intellectual skills are categorized by complexity. Gagné (Gagné, Briggs, & Wager, 1992, p. 54) defines the five levels of intellectual skills (from highest to lowest in complexity) as,

“Problem solving involves the formation of higher-order rules which require as prerequisites rules and defined concepts, which require as prerequisites concrete concepts, which require as prerequisites discriminations.”

Problem solving is defined as the ability to use higher-order rules to invent solutions to complex problems (Gagné, Briggs, & Wager, 1992). These higher-order rules are simply combinations of simpler rules and defined concepts (Gagné, Briggs, & Wager, 1992). Rules and defined concepts are the knowledge of relationships and the ability to classify objects and events (Gagné, Briggs, & Wager, 1992). Concrete concepts are defined as the ability to identify an object’s property or object’s attribute (Gagné, Briggs, & Wager, 1992), for example color, shape, and so on. Gagné states that discriminations are the basis of this five level approach to intellectual skills. Gagné (Gagné, Briggs, & Wager, 1992, p. 56) describes a discrimination as the “capability of making different responses to stimuli that differ from each other along one or more physical dimensions.” Of the five levels, discrimination is considered more of a behavioral performance, while the other four levels (problem solving, higher-order rules, rules and defined concepts, and concrete concepts) are considered variations of complex cognitive processes. The combination of all five
steps is known as the cumulative nature of human learning (Gagné, Briggs, & Wager, 1992).

Verbal information, one of Gagné's remaining four categories of learning, plays a significant role in design and delivery of computer-assisted instruction. Verbal information is considered the type of knowledge that the learner is capable of stating. Gagné (1985) theorizes that verbal information, or verbal knowledge, is stored as a network of propositions. Verbal information may be delivered to the learner in the form of oral speech, or through the use of printed words or illustrations (Gagné, Briggs, & Wager, 1992). The learning themes presented in Gagné’s verbal information category can be easily applied to the theory of visual learning, and hence warrant further discussion. Gagné (Gagné, Briggs, & Wager, 1992) defines three types of verbal learning environments: labels, facts, and organized knowledge.

In learning labels, the student is simply able to state the name of the object. Learners use many strategies for remembering label names, including mnemonic techniques and word associations. Another example of learning labels includes the use of learner-generated images to cue the retrieval of words (Gagné, Briggs, & Wager, 1992). Knowing the name of an object is quite different from knowing the meaning of the name. "To know the object as a concept (that is, to know its meaning), he or she must be able to identify examples and non-examples that serve to define and delimit the class" (Gagné, Briggs, & Wager, 1992, p. 81). While knowing the name and knowing the meaning can be considered two separate learning activities, Gagné (Gagné, Briggs, & Wager, 1992, p.
recognizes that "in practice, a name for a concept is often learned at the time the concept itself is learned, or just prior to that time."

Learning facts is different activity from learning labels, as a fact is a verbal statement that expresses the relationship between two or more named objects (Gagné, Briggs, & Wager, 1992). Facts are either learned in isolation, or in connection with other known facts. Gagné (Gagné, Briggs, & Wager, 1992) points out that facts can typically be looked up, rather than memorized. However, by memorizing facts, the learner simply has the needed information at hand, stored in memory. In designing instructional materials, Gagné (Gagné, Briggs, & Wager, 1992) stresses the obligation of the designer in deciding how much information, in terms of facts, will be given to the user. Gagné (Gagné, Briggs, & Wager, 1992) lists three key elements which should be examined when deciding to include or exclude certain facts from the instructional material. First, some facts which are less relevant to the instructional goals should be left to the learner to look up. Second, facts that are required for frequent reference should be included in the instructional material. Gagné (Gagné, Briggs, & Wager, 1992, p. 82) states, "Learning these facts would be an efficient strategy." Third, facts which are of such "fundamental importance that they ought to be remembered for a lifetime" (Gagné, Briggs, & Wager, 1992, p. 82) should be included.

Organized knowledge takes the learning of facts one step further. Organized knowledge is interconnected facts that form larger bodies of knowledge. Gagné (Gagné, Briggs, & Wager, 1992, p. 83) states that, "Larger bodies of knowledge are organized from smaller units so that they become meaningful wholes." Organization appears to be
the key to remembering bodies of knowledge (Gagné, Briggs, & Wager, 1992). This organization occurs as a result of "generating new ideas that relate sets of information already stored in memory" (Gagné, Briggs, & Wager, 1992, p. 83). Organization, when carried out during the learning process, aids in the retrieval of information by providing affective cues to retrieval." (Gagné, 1985).

To support the acquisition of intellectual and verbal skills, (as well as cognitive strategies, motor skills, and attitudes), Gagné (Gagné & Briggs, 1979) recommends a five step process for instructional design. These five steps include: 1) instruction must facilitate the learning of the individual student, 2) short-term (daily) goals must be considered a part of a long-range plan, 3) instruction must lead to the development of the individual, 4) a systems approach must be used when designing instruction, and 5) most, importantly--instruction must be based on knowledge of how learning occurs.

**Concluding Remarks**

Skinner's operant conditioning theory can be easily incorporated into the design and development of drill-and-practice computer-assisted applications, "emphasizing the acquisition and retention of simple behaviors" (Chambers & Sprecher, 1983, p.107). In regard to cognitive learning, Gagné's interactionist approach emphasizes an instructional design process that is based on problem-solving and higher-level thinking skills. These two skills can be addressed in development and use of computer-assisted tutorials where the "material presented is not usually facts, but rather concepts, generalizations, and principles, and the like" (Chambers & Sprecher, 1983, p. 130).
The Concept of Visual Learning: Neurological Theories of How the Human Brain Stores Information Acquired from Text and/or Images

Within the study of neurological functions, cognitive theorists study how the human brain stores information acquired from text and/or images. For this section, four theories (and their supporting theorists) have been selected for discussion. These theories include dual coding, single coding, the synthesis of the dual and single coding, and the mental model theory.

The underlying importance of each theory is its explanation of how text and images are "represented" in memory. Richardson (1980, p.37) summarizes the term representation as "a spatial or temporal configuration of symbols which is conventionally regarded as standing in a certain relationship to something else." It is the human brain that creates, stores, and retrieves these representations. Representations are the results of information processing. Borsook and Higginbotham-Wheat (1992, p. 8) give a general explanation of how information is processed:

"Information is first received and recognized and is then either encoded and stored for later retrieval or is lost. The stages of information processing -- recognition, short-term (working) memory storage, and long-term memory storage -- are dependent on internal processes."

For each theory discussed in this study, the aspects of internal processing and mental representation will be addressed.

*Dual Coding Theory*

Paivio (1986; Clark & Paivio, 1991) discusses internal processing systems in his dual coding approach to knowledge representation. According to this theory, information
is processed in two functionally independent, yet interconnected systems. The nonverbal representational system include shapes, environmental sounds, actions, and sensations related to the expression of emotions. The verbal system contains representations of visual, auditory, and articulatory information. Bell-Gredler (1992) separates the two representational systems according to a more pragmatic distinction, whether the information is of a concrete nature or an abstract nature. Concrete objects or events are stored in the nonverbal system, whereas abstract objects, such as linguistic structures, are stored in the verbal system. Objects that have both concrete and abstract characteristics may be coded in both systems. A second perspective of how the two representational systems handle different information is offered by Molitor, Ballstaedt and Mandl (in Mandl & Levin, 1989, p. 7). They state that:

Text is predominantly processed and stored in the verbal system - only the concrete information of the text is visualized and thus also transmitted into the imaginal system. Images, on the other hand, are primarily processed and stored in the imaginal system, yet at the same time they enter the verbal system as a partially verbalized copy. Therefore, dual coding is possible in principle for text, as well as for images, however, mainly for pictures which are doubly stored.

While it is important to recognize the different perspectives of the how text and images are processed, the main significance of the dual coding theory is the independence, yet interconnectedness, of the two representational systems: nonverbal (concrete or in an image format) and verbal (abstract or in a text format). The two types of associations that occur within these two systems include associative connections and referential connections (Figure 2) (Clark & Paivio, 1991). Associative connections are those which join, or link representations within each independent system (nonverbal to nonverbal
Dual Coding

Central Processing

Peripheral Processing

Referential connections are those which form an interconnected representation between the two systems.

Associative connections join representations within each independent system.

Two Modality-Specific Processing Systems

(Adapted from Mandl & Levin, 1989)

Figure 2
or verbal to verbal). Referential connections are those which form an interconnected representation between the nonverbal and verbal system (nonverbal to verbal or verbal to nonverbal).

Associative connections within the nonverbal system include image to image links based on physical properties, sights, and sounds. Paivio and Clark (1991) give an example of a science experiment, and the formation of links based on images of the science laboratory (e.g., shapes of the glassware) and certain smells related to a science experiment, such as natural gas. Within the verbal system, associative connections are made when words are joined to other related words. Paivio and Clark (1991) give an example of the word "metal" and the possible verbal connections that can be made, such as gold, lead, or iron.

Links between the two representational systems are called referential connections. Referential connections include image to word connections (nonverbal to verbal) and word to image (verbal to nonverbal) connections. A referential connection between the nonverbal to verbal system would include visualizing different states within the United States and then being able to name them based on their imaged outline. An example of a referential connection between the verbal to nonverbal system would include the spoken name of a country and the visual image of the country's outline (Clark & Paivio, 1991).

The dual coding theory postulates two independent processing systems, which are mode specific (nonverbal and verbal). Associative connections are created among the representations within each independent system as the learner processes more information. Referential connections are formed between representations in the two independent
processing systems. The referential connections from the synthesis of the two systems, allow the integration of the independent representations into an expanded knowledge base.

**Single Coding Theory**

In contrast to the dual coding theory, Pylyshyn (1981, 1986) is the main proponent of the unified information processing model, termed single coding (Figure 1: Approach III). Molitor, Ballstaedt, and Mandl (in Mandl & Levin, 1989, p. 7) provide this understanding of the single coding theory: "knowledge is stored in a unique memory system in a propositional format independent of whether it was decoded as linguistic or visual information." Kieras (1978, p. 534) defines "propositional" mental coding as "an amodal, abstract form of representation." This is in direct opposition to the dual coding approach which postulates separate mental representations of text and images. Within the single coding approach, the final representation stored in memory is in neither a linguistic or imaginal format, but a blended, abstract format (this form of representation is also common to Gagné's cognitive model).

The single coding theory (Figure 3) shares the same peripheral processing path as both the dual coding and the dual coding/single coding synthesis models. All three models recognize that at the initial level (peripheral processing), text and images are comprehended by two separate processes, one for text and one for images. This distinction is accounted for in how text, with the left-to-right eye movement, differs from picture comprehension, with its multi-dimensional levels and spatial relationships (Farah, in Mandl & Levin, 1989). The single coding model diverges from the dual coding
Single Coding

Propositional format independent of the original linguistic or visual format.

Central Processing

Peripheral Processing

Common internal cognitive processes.

Modality-specific encoding processes.

Modality-Specific Encoding/ Common Cognitive Processes

Figure 3

(Adapted from Mandl & Levin, 1989)
approach at the central processing level. At the central processing level, all information, regardless of its initial value, is transformed into the propositional format.

**Dual Coding/Single Coding Synthesis**

Combining the opposing concepts of both the dual coding and single coding theories, Kosslyn (1981, 1984, 1988) promotes a theory that combines aspects from both representational models. His theory is described in this study as a synthesis of both the dual coding and the single coding models (Figure 4).

All three models presented share the initial peripheral processing path, recognizing that at the perceptual level, text and images are comprehended by two separate processes, one for text and one for images (Figure 1). The synthesis model and the dual coding model share the same initial form of cognitive representation. Recognizing this common feature of both models, Farah (in Mandl & Levin, 1989, p. 62) explains that “some of the differences between the external representation of text and pictures are preserved, even at the internal cognitive levels of representation, and that the processes that act on those representations, to store, access and manipulate them, are correspondingly distinct.” Kosslyn (in Block, 1981, p. 215) states that at this initial internal cognitive level, “the properties of the surface images are in part a consequence of the properties of the medium in which it occurs.” In other words, text retains linguistic characteristics, while images retain some of their initial properties (color, shape, balance, etc.).

The synthesis model and the single coding model share the same final format of cognitive representation. In the final level of knowledge representation, the processing paths converge, forming an amodal system. Here, all knowledge is transformed into a
Dual Coding/
Single Coding
Synthesis

Propositional format independent of the original linguistic or visual format.

Central Processing

Peripheral Processing

Common internal
cognitive processes.

Modality-specific
peripheral
processing and
initial central
processing.

Modality-Specific Encoding & Some Modality-Specific Central Processing/
Final Propositional Format

(Adapted from Mandl & Levin, 1989)
propositional format. Kosslyn (in Block, 1981, p. 218) defines this propositional format as an "abstract language-like discursive format, corresponding roughly to simple active declarative statements.

**Mental Model Theory**

To understand some forms of scientific information and data may involve building mental models of the systems described in the text (Hegarty, Just, and Morrison, 1988). A mental model is defined as "the representation of a limited area of reality in a format which permits the internal simulation of external processes, so that conclusions can be drawn and predictions made" (Molitor, Ballstaedt, & Mandl, in Mandl & Levin, 1989, p. 10).

Mayer (1989) theorizes that mental models are built when the learner attends to the relevant information and builds internal connections based on the relationships presented within the text, as well as builds external connections to related data. After several studies, Mayer (1989) provides the following guidelines designed to promote the development of effective mental models: 1) the to-be-learned material must be potentially meaningful to the learner; 2) the instructional media must evoke meaningful learning (e.g.: high-quality illustrations); and 3) performance tests that measure meaningful learning (e.g.: use the information presented to creatively solve problems).

It is clear that the mental model theory recognizes the representational importance of both text and images. Based on the significant usage of images within the mental model theory, this theory disputes the single coding model (Molitor, Ballstaedt, & Mandl, 1989, in Mandl & Levin, 1989). The basis for this dispute is the picture-like
representations that occur within the mental model theory, and the amodal, linguistic-like representation that occurs within the single coding theory.

**Concluding Remarks**

To date, no single conclusive theory has been developed to explain the hidden, internal processes that govern the representation of text and pictures. The four theories presented: dual coding, single coding, the synthesis model, and the mental model theory, were selected based on their prominent, cognitive-psychological significance.

In reference to education, the four theories presented have direct and different impacts on the process of learning. Each differs in the theory of how the learner comprehends and utilizes text and imaginal information. Molitor, Ballstaedt, and Mandl (in Mandl & Levin, 1989) describe each theory in terms of its importance to the learner. If the theory of dual coding is an accurate representational model, individual differences and learning styles play an essential role. Within this theory, the use of text and images must take into account the learner's ability to comprehend and think in both a concrete and abstract manner. If one accepts the single code theory as an accurate representational model, the mode of presentation becomes a lesser issue. A more important issue within the single coding theory is that pictures and text must be describable and comparable as propositional (abstract) terms. The synthesis model is a combination of the different processing paths presented in these two directly opposing theories. The mental model theory is a combination theory as well, recognizing the importance of text and images. Of the four models presented, the synthesis model and the mental model approach offer educators a moderate position for approaching this complex, neurological issue. While
the theories discussed above postulate different neurological mechanisms, all of the
theories agree that both text and images are crucial in the formation of integrated mental
representations.

The Concept of Visual Learning:
External Theories of How Text and Images
Assist the Learner in the Knowledge Acquisition Process

While the internal theories of mental representations are mainly concerned with the
central processing mechanisms, all four theories presented above agree on the critical
nature of text and images at the perceptual processing level. Mayer and Gallini (1990, p.
715) offers this pragmatic explanation of the importance of integrating text and pictures:

"In spite of the traditional bias toward verbal over visual forms of
instruction, a growing research base suggest that text illustrations have
important effects on student learning."

The external application of the visual learning theory addresses how text and images can
be used to assist the learner in the knowledge acquisition process.

Richard E. Mayer is a leading cognitive theorist who has performed extensive
research on the educational value of text and images. Through his research, Mayer (1984,
1989, 1990, 1992, 1994) addresses how the integration of text and images can assist the
learner in the knowledge acquisition process. His research results have a direct bearing on
the premise for this study: how can hypermedia promote effective learning within a
science curriculum, specifically the study of geological sciences? Examples from the
Virtual Geology application will be used to demonstrate interpretations (and
implementation) of his research results.
Considering educational significance, Levin (1994) addresses five main functions of images corresponding to knowledge acquisition. These functions include decoration, representation, organization, interpretation, and transformation. A meta-analysis of research related to the use of text and images was performed by Levin, Anglin, and Carney (1987). Findings from this analysis will be discussed, showing how images influence retention and comprehension.

Also addressed in this study is how different learning styles may affect one's ability to implement visual imagery skills. Since one teaching strategy may not be effective for every different learning style, circumstances that qualify the use of visual learning will also be discussed.

**Integration of Text and Images**

Text and images provide two fundamental sources for conveying information to the learner. Images interact with text to produce levels of comprehension and memory that exceed that which is produced from text alone (Levin, Angelin, & Carney 1987). This is specially important in a science curriculum. In particular, students in the science's domain make extensive use of diagrams and images in problem solving (Larkin & Simon, 1987). Larkin and Simon's account revolves around the idea that two-dimensional displays (diagrams and images) can convey more information about relationships than one-dimensional displays (text). They further state that when a diagram or image is sufficiently documented with adjoining text, all relevant information is presented to the learner at one time, resulting in better comprehension and problem solving. Winn (1991) finds the following advantages from the use of textually-illustrated images: 1) they are effective for
showing physical layout, how things are put together, and how they work; 2) they can
serve as schemata that help to organize information; and 3) they can make abstract ideas
more concrete.

To illustrate a theoretical basis for the integration of text and images, the research
work of Mayer (1984, 1989, 1990, 1992, 1994) has been examined. In particular,
Mayer's work of 1984, 1990, and 1994 will be discussed in detail. In demonstrating
Mayer's key points, references to the hypermedia program, Virtual Geology, will be made.
Mayer (1984) describes meaningful learning as a process that involves both the cognitive
processes that are performed by the learner, as well as the information that is presented to
the learner. While his work mainly addresses information in a textual format, however it
can easily be adapted to include learning from the presentation of illustrated images.
There are three stages of cognitive processes (Figure 5) that affect the outcome of
learning from text. They are: 1) selecting, 2) organizing, and 3) integrating (Mayer,
1984).

In the selection phase, the learner is involved in the process of selecting
information from text and adding that information to working memory. During phase
two, organizing, the learner is involved in the process of organizing the selected
information into a coherent structure. In the final phase, integration, the learner is
involved in the process of connecting the organized information to other familiar
knowledge structures already in memory. As the diagram shows, the learner must
progress through all three stages in order for meaningful learning to occur.
Three Processes for Meaningful Learning

- Selecting?
  - Yes → Organizing?
    - Yes → Integrating?
      - Yes → Meaningful Learning
    - No → Partially Meaningful Learning
  - No → Non-Meaningful Learning
- No → No Learning

Adapted from Mayer (1984)

Figure 5
With the different phases for meaningful learning defined, it is important to address how educators can aid the learner in the comprehension process. In this section, each of the three stages, selecting, organizing, and integrating, is addressed in terms of textual aids.

**Selecting**

In the initial phase, it is important to provide a focus for the learner. This can be accomplished by providing the learner with a list of behavioral objectives. Behavioral objectives are precise statements that tell the learner what he/she should be able to accomplish after reading the text. An interpretation of behavioral objectives is shown in Figure 6, a screen print from the *Virtual Geology* program. Stated as the "Learning Objective," each of the six sections of the program (topographic maps, minerals, igneous rocks, sedimentary rocks, metamorphic rocks, and relative dating) begins with a behavioral objective. To assist the learner in accomplishing the stated objective, a section titled "Learning Assistance" is included below the learning objective. The learning assistance statement cues the learner to recognize the important topics of each section.

**Organizing**

In phase two, aids that affect the learner's ability to build internal connections among the elements presented are significant. The educator should provide a coherent structure of the logical relationships among the ideas presented in the text. An illustrative interpretation is shown in Figure 7, a screen print from the *Virtual Geology* program. This screen presents a table that defines the Moh's mineral scale of hardness. The ten minerals that make up this scale, from softest to hardest, are listed, along with practical
Topographic Maps

Learning Objective:

Students should be able to use a topographic map to identify lines of longitude and latitude, townships, ranges, and sections, and use the map's scale, as well as apply specific rules regarding contour lines.

Learning Assistance:

Each topic is addressed in an individual section. By completing the interaction presented in each section you will be able to apply the information presented to any topographic map.

Figure 6: Example of Stated Learning Objective
Definitions and Terms

Mohs Hardness Scale may be the most useful tool you have for identifying the wide variety of minerals.

To assist you in remembering the 10 minerals on this scale, try making up a mnemonic that uses the first letter of each mineral.

The resistance of a mineral to being scratched.

Here is a possibility:
Two
great
cowboys
from
Arizona
offer
quick
trick
circus
donkeys.

<table>
<thead>
<tr>
<th>Mohs Hardness Scale</th>
<th>Common Items–Hardnesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Talc (softest)</td>
<td>fingernail–2.5</td>
</tr>
<tr>
<td>2 Gypsum</td>
<td>copper penny–3.5</td>
</tr>
<tr>
<td>3 Calcite</td>
<td>glass–5.5</td>
</tr>
<tr>
<td>4 Fluorite</td>
<td>steel file–6.5</td>
</tr>
<tr>
<td>5 Apatite</td>
<td></td>
</tr>
<tr>
<td>6 Orthoclase</td>
<td></td>
</tr>
<tr>
<td>7 Quartz</td>
<td></td>
</tr>
<tr>
<td>8 Topaz</td>
<td></td>
</tr>
<tr>
<td>9 Corundum</td>
<td></td>
</tr>
<tr>
<td>10 Diamond (hardest)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 7: Example of Internal Connection using a Mnemonic Device
items recognizable to the student, such as a fingernail, a penny, glass, and a steel file. Also listed is a mnemonic device that shows the learner a way of remembering the ten mineral names. As a way of personalizing the learning process, the learner is encouraged to make up his/her own mnemonic.

**Integrating**

In the final phase, aids that encourage the learner to build external connections between ideas in the text and knowledge that are already in long-term memory are recommended. It should be noted that building external connections requires some time and effort on the part of the learner. For the learner to reach phase three, he/she must successfully complete phases one and two. To encourage external connections, educators can provide activities that require the learner to recall previous information. An interpretation of an external connection is shown in Figure 8, a screen print from the *Virtual Geology* program. On this screen, the igneous rocks Gabbro/Basalt (plutonic/volcanic equivalents) are pictured. Within the text description, common minerals are listed. These minerals were presented to the learner in the earlier section titled Rock-forming Minerals. Here, the learner is having to recall from memory the characteristics of these minerals and make a connection that incorporates the characteristics of these new rocks with the characteristics of previously learned minerals.

In 1990, Mayer's concentration moved from the presentation of text, to the instructional use of illustrations. Mayer and Gallini (1990, p. 715) state, "Techniques for enhancing student's visual learning of scientific information represent a relatively untapped potential for improving instruction." They define a "good illustration" as one that
<table>
<thead>
<tr>
<th>Classification</th>
<th>The following give the plutonic name, the volcanic name, and a description.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gabbro/Basalt</td>
<td>Plagioclase (Anorthite) and Augite, and may sometimes contain Hornblende and Olivine.</td>
</tr>
<tr>
<td></td>
<td><strong>Equigranular Phaneritic Gabbro</strong> (plutonic)</td>
</tr>
<tr>
<td></td>
<td><strong>Vesicular Aphanitic Basalt</strong> (volcanic)</td>
</tr>
<tr>
<td></td>
<td><strong>Granite/Rhyolite</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Diorite/Andesite</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Gabbro/Basalt</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Peridotite</strong></td>
</tr>
</tbody>
</table>

Figure 8: Example of External Connection using Previous Information
promotes the reader's understanding of how a scientific system works. Together they propose two conditions that must be met for illustrations to be effective in promoting understanding of scientific text 1) explanative text -- the text must present a cause-and-effect system that allows for qualitative reasoning about the system; and 2) explanative illustrations -- the illustrations must help the learner build a functioning mental model of the system. Figure 9, a screen print from the Virtual Geology program, provides an interpretation of how these two conditions are met through the use of an illustrated image. The text featured on this screen explains the process of erosion. This cause-and-effect system describes the erosion process where rock fragments and smaller grains that have first been exposed to weathering are then transported to depositional locations, lakes, rivers, alluvial fans, and sand dunes. The image featured on this page demonstrates this process in a visual manner. From this image, the student can build a mental model of the erosion process.

In research conducted for a 1994 article, Mayer and Sims began examining the how educators can help students use verbal and visual information to understand scientific explanations. Their studies, based on Paivio's dual coding theory, examine multisensory environments where visual and verbal processing is handled by two different sense modalities. According to Mayer and Sims, when the learner is able to make both associative connections (connections within one modality) and referential connections (connections between both modalities), the learner's problem-solving ability is greatly enhanced. The basis for this premise is that associative connections and the referential connections will provide a greater knowledge base upon which the learner can draw from
Erosion is the removal of rock fragments and smaller grains from the bedrock by wind, water, or ice.

The sediment eroded may be transported long distances or it may be deposited relatively near the bedrock from which it was eroded.

Sediment may be transported by wind, by streams and rivers, by waves and currents in lakes and oceans, or by glaciers.

Large amounts of sediment are deposited in the oceans, but sediment may also be deposited on the continents in lakes, rivers, alluvial fans, and sand dunes.

Figure 9: Example of Illustrated Image
for completing a given task. The purpose of the Mayer and Sims studies is to determine how the effects of visual and verbal presentations assist the learner in the building of these internal connections. Specifically, they studied whether verbal and visual information presented in either a concurrent manner or in a successive manner results in stronger internal connections. Their prediction is that learners will be better able to build referential connections when the information (verbal and visual) is presented concurrently, rather than successively. Mayer and Sims call this the “contiguity effect” (p. 390).

Mayer and Sims' studies focus on two factors, domain-specific knowledge and general spatial ability. Domain-specific knowledge relates to how much the learner may already know about the particular subject. Spatial ability is defined as the “ability for subjects to carry out tasks which plausibly can only be carried out by manipulating some pictorial representation” Richardson (1980, p. 130). The results suggest that low-experience (i.e., lacking domain specific knowledge), high-spatial learners benefit most from instruction that carefully synchronizes the presentation of verbal and visual forms of scientific explanation. In relationship to the geological science 100 level curriculum, most students enrolled will have a low-experience level with this subject matter. These low-experienced learners are prime candidates for the type of instruction provided by the Virtual Geology computer-assisted application. While a true correlation with Mayer and Sims' studies would also require the learner to have a high-spatial ability, it is possible that the geological sciences students will benefit from the synchronized form of instruction that this application provides. Figure 10, a screen print from the Virtual Geology program, provides an interpretation of the synchronized form of instruction, where both the verbal
Metamorphism of Shale

Shale is a very common type of sedimentary rock. Consequently, metamorphic rocks derived from Shale are also very common. As Shale is subjected to higher and higher grades of metamorphism, different metamorphic rocks are formed.

Phyllite is a low-grade metamorphic rock formed of mica crystals that are too small to see easily.

Phyllite forms when rock that was originally Shale is subjected to low-grade metamorphism. In Phyllite, the mica crystals are larger than in Slate (although still too small to see easily) and they give the rock a sheen, whereas Slate has a dull surface.

Phyllite sometimes has wavy, wrinkled surfaces.

Figure 10: Example of Synchronized Instruction
(text) and visual image are presented contiguously. Within this form of instruction, the learner is able to process both forms of information (textual and imaginal) by accessing and reviewing just one screen of information. This "contiguity effect" is one of the basic design principles of the Virtual Geology computer-assisted application; hypermedia was used to implement this principle. Hypermedia provides a programming method for making the presentation of text and images flow naturally and smoothly, under the user's control.

**Educational Functions**

In 1987, Levin, Anglin, and Carney conducted an empirical investigation of research involving the function of images in prose learning. The premise for this investigation is that not all types of images are equally facilitative of prose learning (Levin, in Mandl and Levin, 1989). Before discussing the results of this investigation, it is important to define the different types of image functions.

Levin (in Mandl & Levin, 1989, p. 85) distinguishes between "text-relevant" images and "text-irrelevant" images as he defines five different types of text-embedded images and the educational function each serves. The five text-embedded image formats are: decoration, representation, organization, interpretation, and transformation. Each image function will be explained in detail. Images from the computer-assisted application, Virtual Geology, will be used to show visual interpretations of the different text-embedded image functions. The first function, decoration, is mainly associated with text-irrelevant images. Decorational images may make a textual passage more attractive, and may also motivate the learner to read the passage. However, decorational images do not support or supplement critical text information (Levin, 1981). Because the decorational-type image
does not have a proven educational advantage (within this study), this type of image has been excluded from the *Virtual Geology* application.

Levin (1981) defines the next three types of image functions as conventional (common formats used within textbooks). These conventional image functions include representational, organizational, and interpretational. Each image format facilitates the learner's prose learning in a different way. In the following sections, each image format is discussed individually.

**Representational Images**

Representational images add concreteness to a text passage. These images represent "actors, objects, and activities taking place in the narrative passages" (Levin, Anglin, & Carney, 1987, p. 55). Within this category, text-embedded images "tell exactly the same story as the textual passages, or overlap substantially with the text. As an interpretation of this image function, Figure 11 from *Virtual Geology* shows how clastic rocks are formed through the precipitation process. The text-embedded image shows the physical aspects of this process. The image also contains key words related to this rock formation process. This image provides a concrete visual foundation for understanding this abstract process. Organizational images are classified as adding coherence to the understanding of the textual passage. An example of an organizational image is an illustrated map that makes geographical relationships more transparent (Dean & Kulhany, 1981). An interpretation of this function is shown in Figures 12 A, B, and C (screens from the *Virtual Geology* application). These organizational images are accessible from
Fluids passing through the buried sediment may precipitate minerals in the pore spaces between grains, cementing the sediment together.

Sediment that has been consolidated through compaction and/or cementation is sedimentary rock. Several minerals can be found as cements, but the most common cements are Calcite, Quartz, and Hematite.

Figure 11: Example of a Representational Image
In the United States, three series of maps have been generally published. The most detailed is the \(7\frac{1}{2}'\) series, which covers \(7\,1/2'\) of latitude and \(7\,1/2'\) of longitude. These are published at a scale of 1:24,000.

Next is the \(15'\) series, which covers \(15'\) of latitude, and \(15'\) of longitude, and is published at a scale of 1:62,500.

Last is the \(1'x2''\) series, which covers \(1'\) of latitude, and \(2''\) of longitude, and is published at a scale of 1:250,000.

Figure 12 A: Example of an Organizational Image
In the United States, three series of maps have been generally published. The most detailed is the 7 1/2' series, which covers 7 1/2' of latitude and 7 1/2' of longitude. These are published at a scale of 1:24,000.

Next is the 15' series, which covers 15' of latitude, and 15' of longitude, and is published at a scale of 1:62,500.

Last is the 1'x2' series, which covers 1' of latitude, and 2' of longitude, and is published at a scale of 1:250,000.

Figure 12 B: Example of an Organizational Image
In the United States, three series of maps have been generally published. The most detailed is the 7 1/2' series, which covers 7 1/2' of latitude and 7 1/2' of longitude. These are published at a scale of 1:24,000.

Next is the 15' series, which covers 15' of latitude, and 15' of longitude, and is published at a scale of 1:62,500.

Last is the 1 X 2' series, which covers 1' of latitude, and 2' of longitude, and is published at a scale of 1:250,000.

Figure 12 C: Example of an Organizational Image
the three hypertext links (underlined words) shown on screen. Beginning with the 7 ½ minute map (Figure 12 A), the learner begins with a visual representation of this mapping format. Here, the learner sees the amount of geographical information available from this format. The second link, the 15 minute map series (Figure 12 B), displays a representation of this size map. This visualization shows the relationship (in terms of size) between the 7 ½ minute map and the 15 minute map. The third link, the 1 degree by 2 degrees map series (Figure 12 C), presents a visual representation of the amount of information presented within this map size. It also shows the relationship between this map size (1 degree by 2 degree), and the 7 ½ minute map and the 15 minute map. With these three hypertext links, the learner is able to view these images in any order, and as many times as necessary. Use of this image function is advantageous in forming a clear mental representation of these different map formats.

**Interpretational Images**

Interpretational images provide clarification of difficult to understand text passages and abstract concepts (Levin, Anglin, & Carney, 1987). These images add to the understanding of the presented text and ideas. An illustration of this image function is shown in Figure 13 (from the Virtual Geology program). Compositional change is an abstract concept, compounded by difficult-to-understand text. This type of compositional change takes place typically within sea-floor spreading (caused by an active fault system). The image demonstrates the process where cold oxygenated ocean water penetrates the volcanic rocks, and therefore the hot magma, on the sea floor. The ocean water, heated by the magma chamber, becomes a reducing solution high in iron. Because of the
Changes and Grade

In some cases the overall chemical composition of a rock may change. This is not truly metamorphism, but metasomatism.

This can only happen if new atoms are added to the rock or are taken away by fluids migrating through the rock during metamorphism.

This is an important way that metallic minerals can be concentrated to form ore bodies.

Figure 13: Example of an Interpretational Image
complexity of this type of compositional change, learners may need further instruction to fully understand this process. However, this image does provide the learners with a visual interpretation of this complex process, and therefore a basis for further discussion.

**Transformational Images**

The final image function is transformational. As compared to the just discussed image functions, transformational images are classified as non-conventional. Transformational images are typically associated with complex issues that are difficult to address in picture format. Levin, Anglin, & Carney (1987, p. 61) state that "transformational images are designed to impact the learner's memory directly." This is accomplished through a three step process that targets the critical information and 1) recodes the information into a more concrete and memorable format, 2) relates the context of the separate pieces of that information, and 3) provides the learner with a systematic means of retrieving the critical information when later asked for it (Levin, Anglin, and Carney, 1987).

An interpretation of the transformational image function is depicted in Figures 14 A, B, and C (screens from the *Virtual Geology* application). These screens, each accessible from the hypertext links provided, explain the latitude and longitude numbering scheme. Calculated as a series of three sets of numbers, lines of latitude and longitude are expressed in terms of degrees, minutes, and seconds. In Geological Sciences 101, learners often want to think of minutes and seconds in the context of time. In this case, minutes
Any point on the Earth's surface can be identified as the intersection of a line of latitude and a line of longitude. It is necessary to specify which hemisphere of latitude and which hemisphere of longitude in which a particular location lies. California is in the Northern Hemisphere (latitude), and Western Hemisphere (longitude).

Latitude and Longitude are expressed in degrees, minutes, and seconds.

1 degree (°) = 60 minutes (60')
1' = 60 seconds (60")

Example: The Pfau Library at CSUSB is at approximately 34°10'56" North Latitude, and 117°18'59" West Longitude.

One degree is a unit of latitude or longitude equal to 1/360 of a great circle.

Figure 14 A: Example of a Transformational Image
Latitude and Longitude

Any point on the Earth's surface can be identified as the intersection of a line of latitude and a line of longitude. It is necessary to specify which hemisphere of latitude and which hemisphere of longitude in which a particular location lies. California is in the Northern Hemisphere (latitude), and Western Hemisphere (longitude).

Latitude and Longitude are expressed in degrees, minutes, and seconds.

1 degree (1°) = 60 minutes (60')
1' = 60 seconds (60'')

Example: The Pfau Library at CSUSB is at approximately 34°10'56" North Latitude, and 117°18'59" West Longitude.

Figure 14 B: Example of a Transformational Image
Latitude and Longitude

Any point on the Earth's surface can be identified as the intersection of a line of latitude and a line of longitude. It is necessary to specify which hemisphere of latitude and which hemisphere of longitude in which a particular location lies. California is in the Northern Hemisphere (latitude), and Western Hemisphere (longitude).

Latitude and Longitude are expressed in degrees, minutes, and seconds.

1 degree (1°) = 60 minutes (60')
1' = 60 seconds (60")

Example: The Pfau Library at CSUSB is at approximately 34°10'56" North Latitude, and 117°18'59" West Longitude.

One second is equal to 1/60 of a minute.

Figure 14 C: Example of a Transformational Image
and seconds do not have any relationship to time, but yet provide a way to account for each fraction of a degree.

The text-embedded images show the relationship among these three sets of numbers. Beginning with the term: degree, this image (Figure 14 A) explains that one degree of latitude or longitude is equal to 1/360th of a great circle (the circle represents the Earth). The text-embedded image on the minute screen (Figure 14 B) explains the relationship between a degree and a minute. It shows that a minute is a fraction of a degree (or 1/60th). The text-embedded image on the second screen (Figure 14 C) shows how all three numbers are related. One second is equal to 1/60th of a minute.

These three screens are displayed in color. While it may appear subtle, the different elements: degrees, minutes, and seconds, are each displayed in a different color. As the learner progresses through the screens (degrees to minutes to seconds), each element builds inside of the other (showing the fractional relationship). With the hypertext links, learners are able to choose and re-choose each link, displaying and redisplaying each element. These images were chosen as the interpretation of this image function because of the complex nature of this material, and the difficulty of portraying this material in a conventional image format.

**Meta-Analysis**

These different image functions provide a basis for the meta-analysis performed by Levin, Anglin, and Carney (in Willows & Houghton, 1987). These three visual-learning theorists have attempted to perform an exhaustive analysis of the studies related to the
function of images in prose learning. After a careful screening process, Levin, Anglin, and Carney selected one-hundred experiments from eighty-seven different studies. Those studies that included decorational images were excluded from this meta-analysis (because they do not directly support the learning process). The intent of this meta-analysis was to compare text-plus-image learning conditions to text-only learning conditions. An effect size of 0.00 indicates that the text plus image group and control group (text only) being compared have the same mean level performance (Levin, Anglin, & Carney in Willows & Houghton, 1987). The results show that all four functions (representational, organizational, interpretational, and transformational) exhibit at least moderate degrees of learning facilitation when compared with the text-only control group. Transformational images showed the most substantial results (more than 1.50 standard deviation units). Results related to the other three image functions (representational, organizational, and interpretational), depicted a more moderate degree of learning facilitation; each type showed more than .75 standard deviation units when compared to the text-only control group.

In summary, Levin, Anglin, and Carney (in Willows and Houghton, 1987, p. 77) conclude that "even though images serving conventional functions (representational, organizational, and interpretational) are facilitative, images serving an unconventional function (transformational) can be even more facilitative." As demonstrated, all four image functions have been incorporated into the Virtual Geology application.
Individual Differences

Mayer and Levin's research provides a solid foundation for the educational integration of text and images. However, Egan and Grimes-Farrow (1982) and others have shown that some people will adopt imagery strategies in solving problems, whereas others will not. Slee (in Fleming & Hutton, 1983, p. 54) reports that "Some people appear to experience and, to hold, clear and detailed images of all kinds of past events with little or no conscious effort; others, myself included, seem to be quite unable to muster up any kind of visual image in the normal working state, even with the expenditure of considerable concentration and effort." These studies indicate that significant individual differences exist in visual imagery abilities. This section will focus on these individual differences, and the implications that these differences have on computer-assisted instruction.

Slee has developed an instrument to "assess the extent to which a subject's spontaneous, or normal mode of representing absent objects is characterized by several relevant dimensions of visual experience, including visual organization and details of color, texture and shape" (in Fleming & Hutton, 1983, p. 58). The scale's possible score range is 0-15 (from low/no imagery ability/propensity to high imagery ability/propensity). With this scale in mind, various studies were performed that tested the learner's ability to encode, store, and retrieve visual information. Results from Slee's studies show what other theorists have reported in the past, that is, "there are some individuals who are unable to apply externally-imposed imagery strategies in learning and remembering, no matter how appropriate these might be in terms of the task presented" (in Fleming &
Hutton, 1983, p. 71). When asked to just visualize the stimulus items, some low-imagers reported. "I don't remember that way." One test subject stated that "Because I haven't got a picture in the first place, so I can't look back to a picture, and because I wasn't saying [the names of the pictured items], I don't have the word to recall either."

These accounts from low-imagers have a definite implication for both classroom and computer-based learning. When considering different learning activities, the needs of all learners, low-imagers to high-imagers, must be taken into account. Designing a computer-assisted application that utilizes key words, as well as images, "capitalizes on the capacities of efficient imagers without simultaneously causing disadvantages for poor imagers or non-imagers" (in Fleming & Hutton, 1983, p. 71). All figures shown thus far from the Virtual Geology application illustrate the combined use of key words and images. Therefore, under Slee's description, the Virtual Geology application would serve as a beneficial learning tool for both low-imagers and high-imagers.

**Concluding Remarks**

Through time, theorists will continue to debate the advantages of text-only prose versus text-plus-images prose. The fact remains, that most educational material used today does contain text-embedded images. Levin and Mandl (1989) point out that students in the science domain make extensive use of images and diagrams. With this in mind, educators who are designing and developing new learning materials should spend a considerable amount of time designing and selecting those images that will provide the most educational benefit. The four different types of images presented by Levin provide a basis for this selection process. Slee's research theorizes an actuality that all educators
must address; that is, not all learners possess the same visual imagery ability. In summary, successful computer-assisted applications, such as Virtual Geology, will: 1) consist of the correct screen layout that supports Mayer and Sims' contiguity effect, 2) contain images that are either representational, organizational, interpretational, or transformational, and 3) address the needs of both non-imagers and high-imagers.

**Computer-Assisted Instruction:**
Advantages and Disadvantages, Types, and Tools

Educational technology has experienced many advances since the development of the first computers in the 1940s. These computers, termed "mainframe computers and, later, minicomputers stimulated visions of new approaches to learning" (Lockard, 1992, p. 3). The development of PLATO (Programmed Logic for Automatic Teaching Operations) at the University of Illinois in 1959, was one of the first mainframe-based educational authoring systems that allowed educators to create their own tutorials (Venezky and Osin, 1991). In 1971, TICCIT (Time-shared Interactive Computer Controlled Information Television) was developed. This system used a television and graphics to present concepts and teach the use of rules (Bitter, 1989). In 1976, the first microcomputers became available, promoting an educational dream to a technological reality. In the late 1970's, the first Apple computer was introduced, and soon other manufacturers, such as IBM, ATARI, Commodore, and Radio Shack would "begin tailoring some of their products to classroom applications" (Bitter, 1989, p. 47).

The 1980's are well-known for the introduction of microcomputers into homes and schools. However, the lack of well-designed educational software was a crucial issue. In
these early years, educators used a programming language called “BASIC” (Beginners All-purpose Symbolic Instruction Code). “BASIC was developed in the 1960s at Dartmouth College to be an easy-to-learn language for beginners” (Lockard, 1992, p. 13). BASIC allowed new computer users to easily create computer-assisted instructional materials. However, early microcomputer programming languages, such as BASIC, depended upon interpreted flow-control logic (one statement following the next statement). This form of flow-control limits the development of complex, multi-branching recursive structures. Because the program logic only progresses forward through each line of code, it is difficult to create a program in BASIC that allows the user to repeat any section of the application in any order, multiple times. As a result, programs created with the early versions of BASIC were best suited for delivering instruction based on behavioral skills (stimulus/response, repetitively).

"Of the learning theories supporting computer use in education, behaviorism has had the greatest impact" (Simonson & Thompson, 1990, p. 25) Behaviorism is based on the principle that instruction should be designed to produce observable and quantifiable results (Simonson & Thompson, 1990). “Behaviorists ignore the cognitive changes that internally occur during teaching and maintain that it is impossible to design instruction on what happens in a learner's brain because these changes are not observable, not measurable, and are impossible to predict” (Simonson & Thompson, 1990, p. 34). "Cognitive theorists focus on the exploration of the way information is received, organized, retained, and used by the brain" (Simonson & Thompson, 1990, p. 34) Cognitive theorists agree that computer-assisted instruction needs to be “organized and
delivered in a way that compliments the cognitive structure and level of sophistication of the learner" (Simonson & Thompson, 1990, p. 34).

Both behaviorism and cognitive theory guide the development of computer-assisted instructional materials. Because of their influence, Simonson and Thompson (1990) prefer to look at the "commonalities" that exist within these two theories. Two of the commonalities are: 1) feedback and 2) the need for individualized instruction. The use of feedback is advocated by both theories. While feedback is used by these two theories in slightly different manners, the learning outcome is still the same. For example, on the behaviorist side, feedback is used "to modify behavior" (Simonson, & Thompson, 1990, p. 36). Cognitive theorists prefer to consider the use of positive feedback as a way to correct mental function (Simonson & Thompson, 1990). "To correct mental function" is a variation of the wording "to modify behavior," and essentially the same outcome occurs: a change in future performance. The second commonality is the "importance of individualized instruction" (Simonson & Thompson, 1990, p. 36). Both theories recommend individualized instruction as a way to meet the special needs of each student. Behaviorism advocates direct, individual responses to specific stimuli. Cognitive theory promotes a variety of learning paths that encourage individualized choices. With this commonality, the outcome is again similar. In each case, the learner's needs are met based on an individualized approach to instruction. In conclusion, Simonson and Thompson (1990, p. 38) believe that "behaviorism is the most practical, easily applied approach, while cognitive science is by far the most sophisticated approach." Applied examples of both theories will be documented in the following sections.
In this portion of the study, a retrospective of computer-assisted instruction is offered. This section details the advantages and disadvantages of computer-assisted instruction, examines two different categories of computer-assisted instruction, and provides an examination of the different authoring tools used for developing computer-assisted instructional materials.

Advantages and Disadvantages of Computer-Assisted Instruction

Computer-assisted instruction can be defined as the use of computer-based materials to assist the learner in understanding ideas and in acquiring information too complex for verbal explanation alone (Kemp & Smellie, 1989). The term “computer-assisted instruction” is analogous with the term “computer-based learning.” “Whichever term is used, the process is the same: computers are used to teach, drill, and test students of all ages and abilities on a virtually unlimited range of subjects” (Bitter, 1989, p. 240). In 1989, Bitter produced a fairly comprehensive list of both advantages and disadvantages regarding the use of computer-assisted instruction. Due to budget constraints and other reasons, many schools have been slow to implement a curriculum that utilizes computer-assisted instruction, and this list of advantages and disadvantages is still relevant today.

On the side of advantages, Bitter (1989) describes seven uses that promote both the possibilities and benefits of computer-assisted instruction. These include:

1. The use of computer-assisted instruction involves the learner in an active process. Computer-assisted instruction differs from traditional lecture-type instruction which promotes a passive learning style. Computer-assisted instruction, with the necessary input and responses, requires each student become an active participant.
2. Computer-assisted instruction can provide fast and systematic feedback that motivates the learner to progress through the material being presented.

3. Computer-assisted instruction allows all learners to progress at their own pace. In a traditional classroom, the group must progress at the same rate. With computer-assisted instruction, learning becomes a much more individualized process, allowing each student the necessary time to complete each lesson.

4. Computer-assisted instruction can fulfill the need for remedial training. Applications can be developed that allow students to practice concepts and skills, without consuming valuable class time.

5. The use of computer-assisted instruction can free the teacher to concentrate on more valuable tasks, such as offering individual assistance to students in need.

6. Computer-assisted instruction can provide real-world experiences to students in a classroom. By using a form of computer-assisted instruction called a simulation, students can experience life-like realities through the use of a computer application.

7. The use of computer-assisted instruction provides students with computer literacy skills. The mere exposure alone to computer technology increases the student's comfort level, giving the student a safe environment to explore and learn.

While the advantages make the use of computer-assisted instruction seem very promising, Bitter (1989) describes four factors, or disadvantages, that should be taken into consideration when implementing new technology. For each factor, Bitter provides suggestions for overcoming the stated disadvantage. The four factors include:

1. Some people may feel that computer-assisted instruction dehumanizes the instructional process. The fear that computers will replace the human teacher, indicates the very importance of the social experience that takes place in the classroom. To combat this fear, Bitter (1989, p. 246) suggests that teachers should view the computer as a tool that can be used to supplement the educational process, rather than as a replacement for the teacher-student interaction.

2. For full utilization of computer-assisted instruction, teachers will need proper training, on top of their already heavy workloads. For some teachers, the fear
of not being a computer expert also prohibits their implementation of new technology. Bitter (1989, p. 248) stresses that "teachers do not have to be computer experts before they can use computer-assisted instruction. Rather, teachers can learn how to work with computers right along with their students."

3. Budgets often limit the implementation of new technology, including computer-assisted instruction. In 1989, Bitter (p. 249) indicated that "as more educational software publishers appear on the scene, competition heats up and costs are reduced. Therefore, costs associated with computer-assisted instruction are becoming less of an obstacle all the time." This statement is still relevant in today's educational computing market. Computing technology has advanced drastically since 1989. The prices associated with computer hardware and software, including computer-assisted instruction, continue to decrease.

4. In 1989, Bitter (p. 249) describes the fourth factor as "computer-assisted instructional software is just coming into its own, and some users prefer to wait for further development." As Bitter (1989, p. 249) concludes "the picture is much brighter now. Recognizing the great potential market of educational users, software publishers are devoting more time and money to designing high-quality computer-assisted instructional software" While these statements were made in 1989, it is important to note their relevance to today's educational environment. At some point, educators who have not already implemented computer-assisted instruction in any form will need to look at the advantages shown above, and re-evaluate their teaching styles.

**Types of Computer-Assisted Instruction**

"Computer-assisted instruction describes the use of computers for instructional tasks" (Bitter, Camuse, & Durbin, 1993, p. 85). While computer-assisted instruction is available in several distinct formats, two of the most commonly used types have been selected for discussion within this study. These include: 1) drill and practice, and 2) tutorials.
Drill and Practice

Drill and practice, a common form of computer-assisted instruction, employs a repetitive, or flash card, approach to emphasize rote memory (Chambers & Sprecher, 1983). As stated earlier, Skinner's operant conditioning theory can be easily incorporated into the design and development of drill and practice computer-assisted applications, "emphasizing the acquisition and retention of simple behaviors" (Chambers & Sprecher, 1983, p.107). Bitter, Camuse, and Durbin, (1993, p. 61) describe drill and practice applications as software that "allows learners to come in contact with facts, relationships, problems, and vocabulary until the material is committed to memory or until a particular skill has been refined." “The word drill suggests a large volume of highly repetitive work, often done within a limited time frame” (Lockard, 1992, p. 153). The term “practice” refers to the display of questions more than one time. For example, the designer of drill and practice applications can program the application to “expect two correct responses to every item, or two without an intervening error” (Lockard, 1992, p. 153).

A practical implementation of drill and practice software is in the field of mathematics, where the learner is presented with a stimulus (in the form of a mathematical problem) and expected to respond (with the correct answer), repetitively. The program can then test the learner on the mastery of the skills presented (such as the memorization of times tables). Drill and practice software is not limited to the field of mathematics. Another practical example of its use is in vocabulary development. The drill and practice application can present a definition, and the learner is expected to type in the correct word that fits the displayed definition.
Bitter, Camuse, and Durbin emphasize that drill and practice applications do not have to be “so mundane as described; gamelike formats, contextual clues, rhymes, riddles, can all add interest” (1993, p. 62). Lockard (1992) provides the following three-part perspective on why the use of drill and practice applications often fail to meet the expectations of both the teacher and the learner:

1. Drill and practice applications often misuse graphic images. A common practice is the inclusion of decorational images, rather than images that contribute more appropriately to the educational goal.

2. The feedback provided often fosters the opposite of its intent. Graphics or animation that is overly used for either feedback or reinforcement may prevent the learner from working at an efficient pace.

3. Developers of drill and practice applications often remove a question from rotation after the student responded correctly to the question on the first response. “Learning theory suggests that the item needs further rehearsal before it is lost again, if it is to move into long-term memory” (Lockard, p. 157).

When evaluating drill and practice applications for implementation in the classroom, educators are encouraged to evaluate the software based on the following criteria (Bitter, 1989):

1. Students should be able to choose the number of questions that will be presented, and have the ability to end the session when deemed appropriate.

2. Well designed drill and practice software should recognize a wide range of commonly made errors and provide hints, suggestions, and even a review of the material to the learner.

3. The drill and practice software should use a variety of methods for gaining and holding the student’s attention. As described above, common formats include a gamelike appearance, or use puzzles, riddles, rhymes, and clues to attract the learner not only once, but repetitively.
4. Well designed drill and practice applications allow the teacher to customize the use of the software for each individual student. The teacher should be able to determine the skill level of the information presented, as well as the time allotted for response.

**Tutorials**

“The purpose of tutorial computer-assisted instruction is to provide initial or remedial instruction directly” (Lockard, 1992, p. 255). With tutorial computer-assisted instruction, applications can be designed to present “new concepts and skills through the use of text, illustrations, descriptions, questions, and problems” (Bitter, 1989, p. 253). In regard to cognitive learning, Gagné’s interactionist approach emphasizes an instructional design process that is based on problem-solving and higher-level thinking skills. These two skills can be addressed in development and use of computer-assisted tutorials where the "material to be presented is not just facts, but rather concepts, generalizations, and principles, and the like" (Chambers & Sprecher, 1983, p. 130).

Tutorial applications can take the use of drill and practice software one step further by commonly presenting a “series of lessons followed by drill and practice exercises that test whether a student has mastered the lesson and is ready to progress” (Bitter, 1989, p. 254). Bitter (1989) explains how Gagné’s nine sequential instructional events (identified earlier) can be directly met through specific uses of tutorial computer-assisted applications:

1. Attending: Tutorials must first capture and hold the learner’s attention.

2. Expectancy: The tutorial must state a meaningful learning objective.
3. Retrieval: Tutorials can be used to review any necessary prerequisite material before proceeding with the intended lesson.

4. Selective perception of stimulus features: With the sound, graphic, color, and animation capabilities, tutorials can provide stimuli that are interesting and motivating.

5. Semantic encoding: Tutorials can provide learning guidance in the form of hints and clues. Such guidance serves to reduce frustration within the learner.

6. Retrieval and responding: Tutorials can be programmed to monitor the learner's performance through the use of the application, not just at the end.

7. Reinforcement: Tutorials that utilize timely feedback maximize the efficiency of the learning process.

8. Cueing retrieval: Tutorials can be designed to measure overall performance by presenting a score of the learner’s progress. Tutorials can also recommend areas that the learner should review.

9. Generalizing: Tutorials can provide an environment that provides reviews and practice exercises that enhance the learner’s ability to transfer the learned information to new situations.

Tutorial applications typically offer two formats of progress: linear and branching (Bitter, Camuse, and Durbin, 1993). Linear applications present all screens of information to all learners, regardless of individual ability or instructional needs. More sophisticated tutorials are designed based on the concept of branching. With a branching structure, each individual learner is capable of choosing his or her own learning path, depending upon knowledge level and ability.

Lockard (1992) attributes much success to the use of interactive tutorials, and states that tutorials “offer significant potential to promote learning” (p. 258). Four successful uses are as follows (Lockard, 1992):
1. Tutorials can be suited to meet common learning needs, such as facts, simple discriminations, rules, simple application of rules, and verbal information of high volume.

2. Tutorials are inherently self-paced. Different users may complete a tutorial in widely varying amounts of time depending upon rate of learning, reading skill and level, and voluntary repetition of segments.

3. "With tutorial computer-assisted instruction, all learners are active and fully involved" (Lockard, 1992, p. 258).

4. Tutorials can assume a major portion of the instructional load, permitting teachers to work with students individually.

While the above four successful implementations of tutorial computer-assisted instruction look promising, tutorials can also fail in meeting instructional needs and goals. Common reasons for failure include too much content for the learner to absorb, inadequate examples, and lack of clarity in the presentation of the material. When selecting tutorial applications for implementation in the classroom, educators are encouraged to evaluate the software based on the following criteria (Bitter, Camuse, & Durbin 1993):

1. The tutorial should capture and hold the learner’s attention.

2. The learner should be able to control the pace of the presentation, with the capability of returning to previously presented information if necessary.

3. The use of graphics and sound should facilitate learning.

4. The tutorial should align with curriculum goals and outcomes.

5. The tutorial should encourage repeated usage.

Concluding Remarks

During the last decade, developments in computer technology expanded the impact of instructional software beyond "drill and practice" (based on Skinnerian concepts) into
tutorial software which incorporated Gagné's hierarchical categories of learning. Current advances in computer software capabilities, particularly in specialized "authoring tools," allow educators to create their own instructional applications which can incorporate drill and practice and tutorial functions.

**Authoring Tools Used to Develop Computer-Assisted Instructional Materials**

Computer-assisted instruction offers many advantages, including learner involvement, individual learning paths, and reduced instructional time from improved course design (Cook, 1989). However, problems with computer-assisted instruction exist as well. These include "ineffective branching routines, confusing visuals, and a lack of learner control" (Cook, 1989, p. 110). In the early days of computers, authoring languages were machine-dependent and limiting. Examples stated above include PLATO, TICCIT, PILOT, and the use of BASIC. As a result, a need has arisen for high-level, machine-independent languages "which have powerful, flexible authoring capabilities providing an adequate variety in stimulus, response, feedback, and lesson control" (Cook, 1989, p. 110). Authoring tools were "created specifically for teachers and educators who wish to create software for their students. In general, these languages contain only the capabilities necessary for writing classroom software and thus are much simplified over more general-purpose languages" (Simonson & Thompson, 1990, p. 353).

In 1987, Apple Computer introduced the first version of the authoring tool *HyperCard*. By using HyperCard, non-programmer types (e.g., educators) were given the power to "customize or create information integrating text, graphics, video, music, voice, and animation" (Shalvoy, 1988, p. 10). Defined, "*HyperCard* is a piece of software that
provides the user with access to decks of cards containing text and graphic elements which can be easily arranged and rearranged into a variety of combinations producing exciting new programs” (Gray, 1989, p. 39). The introduction of *HyperCard* generated two new terms: “hypertext” and “hypermedia.” “Hypertext is a collection of textual information on a specific topic featuring highlighted words known as ‘hot spots’ which can be activated by touch. When activated, the hot spots branch the user to additional information, such as definitions, elaborations, or related material” (Sweeters, 1994, p. 48). Hypermedia is defined as “a multi-voice medium that includes text, static and animated graphics, voice, sound, and music all contained in one delivery system” (Gay, Trumbull, & Mazur, 1991, p. 189). Gay, Trumbull, and Mazur (1991, p. 189) continue by stating that “well designed hypermedia systems allow learners to link information, create their own paths through the material, annotate, and literally construct webs of information.”

Upon its introduction in 1987, *HyperCard* was characterized by the media as a tool for the educator, researcher, and business professional (Ragan, 1988; Langthorne, 1988). Unfortunately, initial versions of *HyperCard* had many limitations, including the lack of integrated color support and the required use of the HyperText programming language. Very few of *HyperCard*’s advanced features were menu-driven and had to be controlled by HyperText scripts. As a result, “HyperText is needed to create stacks that perform more than just the basic linear linking functions” (Ragan, 1988, p. 38). Simonson & Thompson explain that an additional impediment to the widespread use of *HyperCard* “is the fact that the system currently is only available for the Macintosh computer, and
many classroom teachers do not have this hardware readily available to them" (1990, p. 370).

New authoring tools have moved educators beyond the limitations of *HyperCard*, while still employing the benefits of cards, stacks, hypertext, and hypermedia. Authoring programs such as *Linkway*, *ToolBook*, and *HyperStudio* offer "simple scripting language and commands that allow developers to create sophisticated, professional-quality stack-based presentations" (Bitter, Camuse, & Durbin, 1993). These applications incorporate limited additional features, including integrated color support and "flip-book" animation.

Recently, a new type of authoring tool, which uses a different structure, has become available. Object-oriented programs, such as Macromedia's *Authorware*, employ the use of hypertext and hypermedia, but do not use cards or stacks. With an object-oriented authoring tool, the developer creates a string of icons that represent what the user sees and hears, and the types of interactions that occur on the screens. What the user sees and hears can include graphic images, motion video, and audio information. The types of user interaction also vary, including clicking on buttons (hot spots), moving the pointer over a particular area of the screen image to initiate an action, and the ability to click and drag screen objects to new screen locations. *Authorware* increases the sophistication level of finished applications by permitting the developer to create completely functional runtime versions. This means that the learner will be able to access the developed application without having to purchase a version of *Authorware*. It should be noted that *Authorware* is a high-end development package that is not as user-friendly as *HyperCard* or *HyperStudio*. Depending upon the experience of the educator, the learning curve for this
application can be very steep. Educators who choose this tool will most likely invest considerably more time in the development process.

**Concluding Remarks**

The development of computer-assisted instructional materials has "almost exclusively been at the hands of commercial developers and a few enthusiastic educators who have generally worked above and beyond the call of duty to develop their own" (McDonough, Strivens, & Rada, 1994, p. 211). With continued advances in the ease of use, authoring packages provide all educators the capability to design, develop, and implement computer-assisted instructional courseware, regardless of technical background.

The information presented in this section considers the practical implications of computer-assisted instruction from the teacher's perspective. While this perspective is important, educators should also take into consideration important points made by student users of computer-assisted instruction. To gain a students' perspective, Thede, Taft, and Coeling (1994) surveyed users of a computer-assisted instruction program at Kent State University, Ohio. They have summarized the students' comments, which are applicable to any discipline, and offer the following advice to educators:

1. Reward students for using available computer-assisted instructional materials.
2. Make sure that an adequate number of computers are available, and in working order.
3. Integrate the computer-assisted instruction into the curriculum. Inform the students of what will be gained by their using the program.
4. Choose or develop applications that allow learners ultimate control of their learning experience, including such a simplistic request as being able to return to a previous screen.

5. Choose or develop applications that provide the users with an instructive, clear, and concise presentation.

Computer-assisted instruction provides educators the opportunity to augment the traditional methods, materials, and strategies of teaching and learning (Marchionini, 1988). The availability of easily-used authoring tools empowers educators to design, develop, and implement information-rich learning environments. Most importantly, the developers of computer-assisted instruction must ensure that their designs are not technology-driven, but are based on empirical educational theory (Cook, 1989).

**Conclusion: Effective Instructional Design**

This literature review has provided an overview of several of the theories associated with learning: behavioral, cognitive, and neurophysiological. Each individual theory can provide educators with guidelines for design, development, and implementation of computer-assisted instructional materials. However, behavioral, cognitive, and neurophysiological theories are "neither mutually exclusive nor mutually complementary. They may, however, overlap" (Madhumita & Kumar, 1995, p. 58). Kemp and Smellie have reviewed the various learning theories (including Skinner’s operant conditioning theory, Gagné’s interactionist cognitive theory, and the information processing theory) and have developed a list of ten “areas of agreement and similar emphasis” (1989, p. 19). Kemp and Smellie indicate that these ten “psychological conditions and general principles
are important factors to consider in the design and use of any instructional media” (1989, p. 19). Their list includes:

1. Motivation: The learner must have a desire to learn, and the lesson must be relevant and meaningful.

2. Individual differences: Such factors as intellectual ability, personality, and learning style affect the learner’s ability to engage in the learning process and should be taken into consideration.

3. Learning objectives: A stated learning objective should be used to inform the learner of what they can expect to learn from the instructional media.

4. Organization of content: Instructional media should be organized into meaningful sequences. If structured logically, the learner has a better chance at remembering the information later.

5. Prelearning preparation: All prerequisites should be stated, and the learner should be given an opportunity to complete these activities before he or she attempts to learn the new material.

6. Emotions: Learning can be an emotional process that includes fear, anxiety, and excitement. When designing and developing instructional media, the intended emotional level should be examined carefully.

7. Participation: In order for new information to be internalized by the learner, instructional media must involve the learner as an active participant.

8. Feedback/Reinforcement: Feedback increases the learner’s opportunity for progress. Positive feedback, as well as constructive feedback on necessary improvement, can motivate the learner.

9. Practice and repetition: The learner should be continually exposed to new information. Practice and repetition are required for knowledge or a skill to become a confirmed part of a learner’s intellect.

10. Application: For long term retention, the learner should be given an opportunity to apply the newly learned knowledge or skill to a variety of realistic problems or situations.
Smith and Ragan conclude that “reasoned and validated theoretical eclecticism has been a key strength in the field of instructional design because no single theoretical base provides complete prescriptive principles for the entire design process” (1993, p. viii). Within the realm of instructional design, Ertmer and Newby also do not advocate the strict use of one theory over the others, but “stress the usefulness of being well-versed in each” (1993, p. 69). Instructional designers must be able to “intelligently choose, on the basis of information gathered about the learners’ present level of competence and the type of learning task, the appropriate methods for achieving optimal instructional outcomes in that situation” (Ertmer & Newby, 1993, p. 69). “Being knowledgeable about each of the theories provides designers with the flexibility needed to be spontaneous and creative when a first attempt doesn’t work or when they find themselves limited by time, budget, and/or personnel constraints” (Ertmer & Newby, 1993, p. 70).

P.B. Drucker (cited in Snelbecker, 1983, p. 203) summarizes the need for both behavioral and cognitive approaches to instructional design as, “We need the behaviorists’ triad of practice/reinforcement/feedback to enlarge learning and memory. We need purpose, decision, values, understanding—the cognitive categories—lest learning be mere behavioral activities rather than action.”
CHAPTER III: PROBLEM, GOALS, AND IMPLEMENTATION

At CSU, San Bernardino, Physical Geology 101 is a general education course. Students from all disciplines may choose this course to fulfill an undergraduate elective requirement. This course does not require students to have any previous experience with the subject matter, or with physical science in general.

Within this course, students are introduced to a range of detailed subjects, all based on interrelationships. Students are given a lab manual that is text-based with few illustrations. Class time is divided between traditional lecture, where students are first introduced to the subject material, and an activity lab. During the lab sessions, students gain hands-on experience with identifying a wide variety of rock and mineral samples. Due to the fast-paced quarterly format of this University, and the scope of the material covered, students are given little opportunity to study these samples at length before being tested on their knowledge. Given the scarcity and quality of these samples, most students are unable to duplicate their own rock and mineral collections.

This course format poses a grave problem for most educational psychologists. Many believe that in order to commit such arcane and technical knowledge to long term memory, the learner must be able to spend a relatively large amount of time studying the material. In order to fully understand the concepts presented, and to gain sufficient experience with the samples, an alternative method of instruction is needed.

The goal of this M.A. project is four-fold. First, through the use of technology, remove all physical barriers to the information presented. Second, provide the students with high-quality illustrations and color images that expand and enhance each of the
important topics in the lab manual. Three, give students control over the subject matter by providing individualized instruction. Fourth, use the capabilities and non-linear structure of the technology to present the information in a way that assists the students in forming complex mental relationships.

These goals can be accomplished through the use of hypermedia and the implications of several learning theories (specifically, the theory of visual learning). Reushle (1995) describes hypermedia as the extension of text-to-text links (hypertext) to non-linear links between two different forms of information, such as text and images. Visual learning describes how a learner mentally builds a knowledge structure based on the information obtained from texts and images (Mandl & Levin, 1989). By combining hypermedia with the theory of visual learning, educators can build powerful, interactive instruments for teaching and learning.

According to the theory of visual learning, key words and graphics assist the learner in building cognitive associations (or mental models) with several possible outcomes: 1) recall of correct information from short-term memory; 2) integration of the factual components into a conceptual knowledge base; and 3) application of the knowledge base to future situations relating to the geological sciences and the physical world around us.

To test the implementation of hypermedia and the theory of visual learning theory, this author has developed a computer-assisted instructional application. Titled *Virtual Geology*, this application links key terminology to intricate illustrations and high-quality
color images. Designed and developed as a tool for supplementing the classroom experience, *Virtual Geology* provides an effective, interactive learning experience.

Using *Virtual Geology*, the learner is empowered to create his or her own learning path. This non-linear application covers six different subject areas: topographic maps, minerals, igneous rocks, sedimentary rocks, metamorphic rocks, and relative dating. From a menu, the learner can choose any one of the six subjects. Once the subject has been chosen, the learner can then select from a menu of topics covered in that section. At any time, the learner can change from subject to subject, and from there, section to section. The illustrations and color images for this application have been designed and produced based on the four text-relevant image formats outlined by Levin (in Mandl & Levin, 1989). These image formats include: representational, organizational, interpretational, and transformational. As explained above, each image format has a specific purpose and facilitates learning in a different manner.

*Virtual Geology* provides an evolution from traditional, teacher-centered education to a discovery-oriented student centered environment. Through the power of technology, educators can become true facilitators of learning, rather than simply providers of knowledge. Such facilitation is shown in the *Virtual Geology* application. With its implementation into the learning environment, students are given the opportunity to better prepare for each class period, to gain knowledge and sophistication with the material presented, and to begin taking the knowledge learned and applying it to new and more complex situations.
CHAPTER IV: PROJECT REVIEW

Background:
The Creation of Virtual Geology

Physical Geology is a fascinating subject with beauty, symmetry, and complex interrelationships. The author of this study first developed an interest in this subject during her undergraduate degree program; she selected Physical Geology 101 as her Natural Science elective.

In the Physical Geology 101 course a tremendously wide range of technical information is presented to the students. Most students who enroll in the course (including the author) lack any previous experience with this subject material. At the time of the author's enrollment in the course (1991), computer-assisted instructional applications in this subject area were almost non-existent. Students used their textbooks, lab manuals, and their hands-on lab time to familiarize themselves with the course material and to prepare for quizzes and exams. In addition to the required printed materials for the course, a printed lab study guide was available from the textbook company. At best, the reliance on printed material and limited lab time was a difficult way to learn the large amount of new information, especially for a subject that is both highly technical and very visual in nature.

After successfully completing the undergraduate course in physical geology, the author continued to pursue the topic as a hobby. Several years later, in the M.A. program, the author was in a position to choose a topic for a final project and thesis. After evaluating the potential of hypermedia and her own technical experience, the author
sought a project topic that was significantly complex, had substantial value for the learner, and complemented her own personal interests. In order to develop a project to meet these criteria, it became apparent that the author would require easy access to application software, appropriate computing equipment, course materials, and content experts.

Working at CSU, San Bernardino, the author was able to maintain contact with the Geological Sciences faculty. This continued interaction suggested a fertile topic for the M.A. project: to develop a computer-assisted instructional application based on the subject matter presented in the Physical Geology 101 course. After initial discussions with the Geological Sciences faculty members, the author received their commitment to the project, and work began on Virtual Geology. To create this application, a six-step systems design approach was employed. This approach includes the explicit phases of analysis, design, development, formative evaluation, implementation, and summative evaluation (Rizza, 1981). "These six phases are designed to build upon one another to generate instructional material which is integrated, efficient, and above all effective" (Rizza, 1981, p. 278).

The analysis phase began in June of 1995. The design of the project began one month later and was followed in August with the development phase. The development phase required the production of a great number of high-quality photographs and drawings, and lasted through November, 1995. In December, 1995, the application was ready for the formative evaluation phase. Several students enrolled in Physical Geology 101 reviewed the project and faculty members (including Geological Sciences faculty and this study’s reader, Dr. Susan M. Cooper) proof-read every screen.
On December 20, 1995, changes from the formative evaluation phase had been implemented, and the application was ready for duplication. For the implementation phase, *Virtual Geology* was duplicated onto five CD-ROMs. These CD-ROMs were available in the software library for student use in the Academic Computing and Media self-instructional computer lab. Students who enrolled in Physical Geology 101 during the Winter and Spring quarters of 1996 were able to use this application to supplement their studies. Each student who used the application was asked to complete an anonymous questionnaire (Appendix A). In the summative evaluation phase, the results from the questionnaire are reviewed. During this phase, changes and improvements were made to the *Virtual Geology* application. This chapter concludes with a recommendation for the future implementation and usage of the *Virtual Geology* application.

**Systems Design Approach:**

*Analysis, Design, Development, Formative Evaluation, Implementation, and Summative Evaluation*

**Analysis**

Several activities constitute the analysis phase, including prioritizing the learner's needs, determining the scope of the project, and pre-planning for the design and development phases.

**Learner's Needs**

Several processes were used to prioritize the learner's needs. These included this author's own experience with the Physical Geology 101 course, interviews with students currently enrolled in this course, and interviews with the Geological Sciences faculty who had taught this course for several years. Through many discussions with these students
and faculty, the necessity for high-quality visual components and individual user control was determined to be of top priority. It was also determined that a consistent interface would be used throughout the application. This consistent interface would include the availability of menu choices and the physical characteristics (color, shape, and font choice) of the key word links and navigational buttons. A consistent interface is a very important aspect of any computer-assisted application. Without consistency, the user is left to guess at how to use the application, rather than paying attention to the material being presented. It was also decided that each section of the application would have its own custom background. Each background would be chosen based on its relevance to the material presented. This factor is part of the consistency in design. Each custom background will provide a visual cue to the learner indicating which section they were currently working in.

**Determining the Scope of the Project**

With the priorities for the application determined, this author began to look at the scope of the project. Originally, the planned application was going to include all nine sections of the text-based lab manual. After considering the available materials, such as illustrations, color photographs, mineral and rock samples, it was decided that the scope of the application would need to be reduced. While there was access to the content experts and the mineral and rock samples, the Geological Sciences department had very few illustrations or color photographs. This meant that every visual component of the application would need to be created; pictures of mineral and rock samples would need to be taken and illustrations that explained the key concepts would need to be drawn. With
this information, this author decided to eliminate the section on "Mass Wasting." It is the smallest section in the lab manual, and one that was well covered by the lecture and lab.

Another factor that served to reduce the scope of this project was the lack of copyright permission to some of the material featured in the lab manual. In particular, the sections related to Earthquakes and Ground Water were written by persons outside of the University. In the lab manual, the authors of the material are cited, but explicit permission to use the material had not been given for this project. With this in mind, this author decided to not use this material, thus eliminating these sections from the Virtual Geology application. This left the following six sections to be included in the Virtual Geology application: Topographic Maps, Rock-forming Minerals, Igneous Rocks, Sedimentary Rocks, Metamorphic Rocks, and Relative Dating.

**Pre-Planning for the Design and Development Phases**

The third activity in the analysis phase is the pre-planning for the design and development phases. During this time, several different development applications were evaluated, including HyperCard, HyperStudio, SuperCard, and Authorware. For very specific reasons, Authorware was chosen to develop Virtual Geology. Before explaining those reasons, it is important to understand why the other three development applications were not chosen.

After first reviewing HyperCard, this application was not selected based on the amount of programming that would be required to achieve the level of complexity and control desired for the Virtual Geology application. Also, the version of HyperCard that was evaluated did not provide sophisticated color support.
HyperStudio is a common choice for an educator who wants to begin creating multimedia. However, this application was not chosen because it only supports 256 colors. This means that color images and illustrations tend to look "grainy" and "fuzzy," two factors that would have interfered with the high quality desired. The second reason HyperStudio was not chosen was the lack of customized pull-down menus. The only navigation scheme that can be used within a HyperStudio stack is on-screen buttons. This limitation did not provide the high level of user control desired for the Virtual Geology application.

SuperCard is an increment between HyperCard and Authorware. One of the advantages of SuperCard is the ability to create customized pull-down menus within an application, similar to Authorware. However, SuperCard requires as much programming as HyperCard and it only supports 256 colors, the same as HyperStudio. For these reasons, this application was not chosen.

Authorware was chosen as the development package to use to create Virtual Geology. Authorware supports millions of colors, allowing for clear, crisp photographs and illustrations. With Authorware, customized pull-down menus could be created, as well as on-screen navigational buttons for the ultimate in user control. Using Authorware does require some programming when the intended outcome is sophisticated on-screen interaction, but not as much programming as would have been required with HyperCard or SuperCard.

Authorware is an object-oriented development application, which is very different from card-based applications like HyperCard and HyperStudio. Object-oriented
development applications allow for very complex branching and easy control of large amounts of information. This was deemed a necessity considering the overall size of the Virtual Geology application and amount of information to be included in the six sections.

A drawback to choosing Authorware was the cost of the application. The discounted educational rate for this application was $500.00. This is considerably more than the other applications cost. Also seen as a drawback, this author had no prior experience with Authorware nor knew any other developer with such experience. This did pose an initial problem as the learning curve was quite steep. Most of July 1995 was spent learning the fundamentals of this program, which was considerably more time than the other applications would have required. Even with these challenges, the quality and sophistication of the final product is worth the purchase price and time spent learning the application.

Another factor in this pre-planning stage was gaining access to the equipment and other software that would be necessary to develop Virtual Geology. The list of equipment and software included a powerful Macintosh computer, a flatbed scanner, a slide scanner, a high-quality 35mm camera, as well as access to application software such as Photoshop and ClarisWorks. The author is employed by Academic Computing and Media, which offered its full support to this project. A Macintosh 7100 AV computer was loaned for home use which permitted work on Virtual Geology in off-hours. After-hour access to the faculty multimedia lab that housed the flatbed scanner and slide scanner was also provided. Dan Moseley, the media production specialist in charge of photography, loaned this author a sophisticated 35mm camera with a 100mm macro-focus lens for the extreme
close-up shots of the minerals and rocks. The only piece of equipment that had to be purchased was a portable 730 MB hard drive, which allowed transport of the project back and forth between work and home. In this way, images that were scanned at work could be saved to the drive and then later imported into Virtual Geology. As for the additional software applications that were needed, Photoshop (for color correction of photographs and the development of the custom backgrounds) and ClarisWorks (for creating the illustrations), were provided by Academic Computing and Media.

Design

The design phase is divided into several activities, including developing a project storyboard, defining how the user will interact with the application, and defining learning objectives for each section. In Virtual Geology, a good amount of time was spent on the design phase. Creating the storyboard and making critical decisions during the design phase about how the user would interact with the application made the development stage much easier.

Designing a Project Storyboard

A project storyboard can be developed either on paper, or by using a word processing or drawing program on a computer. The storyboard serves as the project outline by defining the different sections of the application and the order of material being presented. A well thought-out storyboard ensures that the learner will progress through the material in an efficient and effective manner. Because a storyboard provides such a strong visual picture of how the application is to function, it is used extensively in the
development stage. The original storyboard for the Virtual Geology application is shown in Figure 15.

![Virtual Geology Storyboard](image)

**Figure 15 Virtual Geology Storyboard**
Defining How the Learner Will Interact with the Application

The above storyboard only shows an outline of the material to be presented. It does not define how the user will interact with each section. From the storyboard, it may appear that the material is presented in a linear, hierarchal fashion. However, based on one of the top priorities for this application, individual user control, it is important to further define how the learner will progress through each section.

There are six sections in the Virtual Geology application. Each section (or topic) is then further divided into individual modules. Once the learner selects a topic, the learner is free to choose whichever module he or she wants to review. The following diagram shows the first pull-down menu, “Choose A Topic,” that the learner will encounter. From this menu, the learner can choose which section he or she wants to review (Figure 16).

![Virtual Geology Main Menu](image)

Figure 16 Virtual Geology Main Menu (Storyboard)

Referring to the storyboard, the “Topographic Maps” section is further divided into seven modules. Each module can be accessed directly, meaning that the learner does
not have to begin with Quadrangles and progress linearly until reaching Contour Line Rules. The diagram shown below demonstrates that when the learner makes a selection from the "Choose A Topic" menu, he or she will be presented with the individual choices of the different modules for that particular section. For example, if the learner chooses "Topographic Maps" from the "Choose A Topic" pull-down menu, a second pull-down menu titled "Topographic Maps" will appear. From this second menu (Figure 17), the learner can choose any one of the seven "Topographic Map" modules.

<table>
<thead>
<tr>
<th>Choose A Topic: (pull-down menu)</th>
<th>Topographic Maps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topographic Maps</td>
<td>Quadrangles</td>
</tr>
<tr>
<td>Rock-forming Minerals</td>
<td>Latitude and Longitude</td>
</tr>
<tr>
<td>Igneous Rocks</td>
<td>Public Land Survey System</td>
</tr>
<tr>
<td>Sedimentary Rocks</td>
<td>True North vs. Magnetic North</td>
</tr>
<tr>
<td>Metamorphic Rocks</td>
<td>Scale</td>
</tr>
<tr>
<td>Relative Dating</td>
<td>Contour Lines</td>
</tr>
<tr>
<td></td>
<td>Contour Line Rules</td>
</tr>
</tbody>
</table>

**TOPOGRAPHIC MAPS**

Stated Learning Objective and Learning Assistance

Figure 17 *Virtual Geology* Topographic Maps Menu (Storyboard)

Once the learner has made a selection from the list of individual modules, the focus of the interaction will switch from the pull-down menus to on-screen interaction using key word links and navigational buttons. Text from the lab manual will appear, with key words underlined (indicating the on-screen interaction). If the student selects an underlined word, then a definition, diagram, example, or further explanation will appear.
When necessary, the learner will be presented with navigation buttons, allowing him or her to progress forward and backward through the material. At anytime the learner will be able to choose a new section (from the "Choose A Topic" pull-down menu) and from this point make a selection based on the underlying modules.

*Defining Learning Objectives for Each Section*

A stated learning objective is provided to inform the student of what he or she can expect to learn from the instructional media. Each section of the *Virtual Geology* application begins with a stated learning objective. The appropriate statement appears after the student has made a selection from the "Choose A Topic" menu. To add to the comfort level of the student, a "learning assistance" statement is also provided. The learning assistance statement indicates how the student can achieve the learning objective. The student can read the objective/assistance statement prior to making a module selection. Faculty members from Geological Sciences assisted in developing the objective/assistance statements for each module. As an example, the "Topographic Map" section begins with the following learning objective/assistance statement (Figure 18):

<table>
<thead>
<tr>
<th>Learning Objective:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students should be able to use a topographic map to identify lines of latitude and longitude, townships, ranges, and sections, and use the map's scale, as well as apply specific rules regarding contour lines.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning Assistance:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Each topic is addressed in an individual section. By completing the interaction presented in each section you will be able to apply the information presented to any topographic map.</td>
</tr>
</tbody>
</table>

Figure 18 *Virtual Geology* Learning Objective/Assistance Statement
Development

The development phase, like the previous two phases, is divided into several activities. During this phase, the storyboard and the other ideas about how the application should function were transformed into a working model using the development application Authorware. Also during this phase, the crucial visual elements were created and integrated into the application. First, the custom backgrounds for each section were produced. These backgrounds were immediately imported into the working model. The other visual elements, pictures of the mineral and rock samples and the illustrations which explained the key concepts, took longer to create. From August through November, this author worked with the photographer and illustrator, David E. Neighbours, to create these key elements. As work progressed on the development of the working model, the visual elements were successively integrated. The first version of Visual Geology was completed in December, 1995.

Creating a Working Model

Creating the working model required a great amount of time. Since this author did not have any previous experience with Authorware, most of July, 1995, was spent just learning the basic logic of the application. This required approximately sixty hours of computer work. To get a feel for how the application functioned, this author began working with just the opening screen, the application directions screen, and one section, "Topographic Maps." This author learned how to import graphic objects and text, and how to create the on-screen interaction buttons. The next item added was the "Choose A Topic" pull down menu (Figure 19). Here, the first conflict arose. When the "Choose A
The next item added was the "Topographic Map" pull-down menu (Figure 20). This pull-down menu allows the learner to see the seven modules within this section. Since this menu item would always change, reflecting the choice the learner had made from the "Choose A Topic" menu, it could not be perpetual. Once again, a call was placed to technical support. In order to have a pull-down menu (one that was not perpetual) and on-screen interaction, the on-screen buttons would need to be programmed to "stay active." Once this author learned the appropriate logic and program script for this type of button, it was not a difficult task to complete, just time consuming. Each of these
experiences did pay off, as the time required to develop the remaining sections was dramatically cut.

As part of the working model, custom backgrounds were created for each section. A different custom background for each section would provide a visual cue to the learner, indicating the current section he or she was working in. This was one of the fun and creative parts of the development phase. In creating these backgrounds, this author used software that comes with the Apple ColorOne scanner, Ofoto. Photoshop was also used to make any necessary color enhancements and to add the titles of the different sections to each background.

For the "Topographic Map" section, a scanned portion of a U.S. Geological Survey topographic map was used. Since U.S. Geological Survey maps are in the public domain and free from copyright restrictions, this scanned image made a perfect background for this section.
When developing the background for the "Rock-forming Minerals" section, an experiment was performed with the color flat-bed scanner. A sample of the mineral, Rose Quartz, was placed on the glass bed of the scanner. This author wanted to determine the difference in the quality of a “scanned” mineral versus a “photographed” mineral. While the scanned mineral image was not as focused or as brilliant as desired, the end result was an interesting pattern. This pattern was duplicated and rotated several times. Once the screen was completely covered, it made an interesting and colorful background for the "Rock-forming Minerals" section.

This author decided on a Granite texture for the background of the "Igneous Rocks" section. This decision was based on the fact that Granite is a very common type of igneous rock. A CD-ROM that included a variety of textures and photographs was purchased, including several Granite textures. However, this author wasn't satisfied with the quality of those images. This left the author with having to create a Granite background from scratch. In the San Bernardino mountains, there are many exposed Granite surfaces. Using a photograph taken of one of these exposed areas, this author was able to create the desired Granite background.

For the "Sedimentary Rocks" section, a clip art photo of a sandy beach was selected. The marble background selected for the "Metamorphic Rocks" section came as a part of the Authorware clip art library. For the last section, "Relative Dating," this author again used the color flatbed scanner. This time, a slab of sedimentary rock that had a fossilized fish on the surface was scanned. Since the “Relative Dating” section discusses
the age and composition of minerals and rocks, this scanned image made a very appropriate background.

Creating the Visual Elements

In determining the learner’s needs, it was decided that high-quality visual components were one of the top application priorities. Unfortunately, the Geological Sciences department did not have any photographs of the specimens in their mineral or rock collections, nor did they have any diagrams for the key components of the lab manual. This meant that each of these elements would need to be created. To do so required a strong collaborative effort among the photographer and illustrator (David E. Neighbours), the Geological Sciences faculty members, and this author. The Virtual Geology application includes over 175 photographs and illustrations. To say the least, this process took several months time to complete.

Photographic Visual Elements

Within Virtual Geology, there are over 75 mineral and rock photographs. The specimens photographed for this application were chosen from the mineral and rock collection actually used in the Physical Sciences 101 laboratory. It was important that the photographed specimens match those that the students are exposed to in the hands-on lab (versus selecting specimens from a more pristine collection). Photographing these rocks and minerals required the use of a high quality 35mm camera with a 100mm macro lens. Each individual photograph warranted an extreme close-up shot that showed the unique characteristics of the specimen. To achieve this, this author worked with the photographer, David E. Neighbours, to create each shot. Decisions, such as choosing the
appropriate setting (indoor or outdoor) and the type of lighting (indirect or direct) that would highlight the individual features of the specimens were made. Experiments with different backdrops, such as black felt for light colored specimens, and light blue paper for darker specimens were also completed. To create the best possible image, many of the specimens were photographed more than one time and under a variety of conditions. In all, over 500 exposures were made. It should also be noted that several staff members from the Academic Computing and Media department assisted in the process. Carey Van Loon offered his expertise with close-up photography, as did Dan Moseley and Steve Burdick.

Taking the photographs was just one step in this process. The images still needed to be digitized, or transferred, to a computer format. Academic Computing and Media has both a slide scanner (for scanning slides and negatives) and a color flatbed scanner (for scanning color prints). This author chose the slide scanner to digitize these images because she felt that the final quality would be better and the process was less expensive. This decision was made by experimenting with both pieces of equipment. Color prints were scanned on the flatbed scanner and the negatives of those same color prints were scanned using the slide scanner. The slide scanner produced images that were richer in color and sharper in focus. Also, the slide scanner can be controlled from within the Photoshop application. This meant that any necessary adjustments to the color balance, hue, or saturation could be easily made during the scanning process. The second advantage to using the slide scanner is the inexpensive cost. For example, to have a roll of film with 24 exposures processed, but not printed, costs approximately $1.75. Having the
same roll of film processed and printed would cost approximately $4.00. With the number of photographs taken, using the processed negatives and the slide scanner (instead of color prints and the flatbed scanner) amounted to a substantial savings.

The last step in the photographic process was importing each image into the *Virtual Geology* application. This author worked with the Geological Sciences faculty to ensure that each image was incorporated with the appropriate descriptive text screen. When deemed necessary, visual cues, such as arrows and boxes, were added to highlight specific features of certain samples.

**Illustrative Visual Elements**

In addition to the photographs, color illustrations and diagrams were needed to explain key concepts within the *Virtual Geology* application. To fulfill this visual need, over 75 illustrations had to be created. This process required a strong collaborative effort among the Geological Sciences faculty, and the illustrator (David E. Neighbours), and this author.

To begin, this author worked with the Geological Sciences faculty to determine the key words that would act as links to the visual elements. Once those key words were determined, this author sketched sample drawings that would serve as models for the illustrator. To ensure accuracy, this author used a variety of Geological Sciences textbooks as reference manuals. From these sketches, David E. Neighbours used the drawing program found within the *ClarisWorks* application to create each illustration. *ClarisWorks* was chosen because it is easy to use, it offers a fairly extensive set of drawing tools, and the graphic files can be easily exported and imported. The Geological Sciences
faculty reviewed each illustration and made suggestions for improvement. Once the illustration received their final approval, it was imported into the *Virtual Geology* application.

The only illustrations used in *Virtual Geology* that were not created explicitly for this application appear in the “Topographic Maps” section. In several instances, the text passages explain different features of the San Bernardino North Quadrangle map. To illustrate these concepts, actual pieces of this topographic map were used. Sections of the map were scanned using the Apple ColorOne flatbed scanner and the *Ofoto* software. Examples include how to identify the existence of mountain peaks, depressions, valleys, and streams, as well as levels of elevation.

*Formative Evaluation*

Formative evaluation is the fourth phase in this six step process. During this pre-implementation phase, the completed application was thoroughly reviewed and tested from a critical viewpoint. Critical review of *Virtual Geology* involved a group of individuals who each looked at the application from a different perspective. The faculty members from Geological Sciences checked each screen for technical accuracy. Dr. Susan M. Cooper reviewed every screen for consistency, as well as correctness in grammar, punctuation, and spelling. David E. Neighbours tested each menu option, key word link, and navigational button. As problems or inconsistencies were noted, this author made the necessary corrections within the application. This formative evaluation phase began the first of December, 1995, and took approximately three weeks to complete.
During this formative evaluation phase, a "Quiz Preview" module (located at the end of the larger sections) was added. Each "Quiz Preview" module was developed based on the actual classroom quizzes that the students are required to take. For example, the "Rock-forming Mineral Quiz Preview" requires the student to identify several mineral samples based on the images shown and characteristics listed. Using the capabilities of Authorware, the student is asked to "click and drag" the image to the correct screen location. If an incorrect location is chosen, the mineral returns to its original location and the student must try again. Once the mineral is placed in the correct location, the student is allowed to continue to the next question.

In addition to the "Quiz Preview" modules, the "Program Credits" section was also added. In this section, the reference manuals used during the development phase are cited, and credit is given to those individuals who have been instrumental in the development of this application. Scanned photographs of the Geological Sciences faculty and the photographer/illustrator, as well as the department logo for Academic Computing and Media have been included. The final storyboard for the Virtual Geology application appears in Figure 21. The shaded areas represent the section and modules added during the formative evaluation phase.
## Virtual Geology

**Main Screen**

### Application Introduction

(instructions on how to use the application)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Topographic Quadrangles</td>
<td>Definitions and Terms</td>
<td>Introduction</td>
<td>Introduction</td>
<td>Introduction</td>
<td>Introduction</td>
<td>Program Creator</td>
</tr>
<tr>
<td>Latitude and Longitude</td>
<td>Mineral Groups</td>
<td>Textures of Plutonic Rocks</td>
<td>Formation of Clastic Rocks</td>
<td>Changes and Grade</td>
<td>Examples</td>
<td>Photographer/ Illustrator</td>
</tr>
<tr>
<td>Public Land Survey System</td>
<td>Key to Minerals</td>
<td>Textures of Volcanic Rocks</td>
<td>Properties of Clastic Rocks</td>
<td>Metamorphism of Shale</td>
<td></td>
<td>Geological Science</td>
</tr>
<tr>
<td>True North vs. Magnetic North</td>
<td>Alphabetical Look-up</td>
<td>Classification of Igneous Rocks</td>
<td>Classification of Clastic Rocks</td>
<td>Metamorphism of Other Rock Types</td>
<td></td>
<td>Academic Computing and Media</td>
</tr>
<tr>
<td>Scale</td>
<td>Quiz Preview</td>
<td>Tips for Identifying Igneous Rocks</td>
<td>Depositional Environments</td>
<td>Metamorphism of Organic Material</td>
<td></td>
<td>Geological Sources</td>
</tr>
<tr>
<td>Contour Lines</td>
<td>Quiz Preview</td>
<td>Chemical and Organic Sedimentary Rocks</td>
<td></td>
<td>Quiz Preview</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rules About Contour Lines</td>
<td></td>
<td>Sedimentary Structures</td>
<td>Quiz Preview</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 21 Final Storyboard for Virtual Geology**
The final task completed during the evaluation phase was the development of the *Virtual Geology* questionnaire (Appendix A). This author worked with the Geological Sciences faculty and Dr. Susan M. Cooper to develop a questionnaire that would assist in the collection of statistical data about the student users. The first page of the questionnaire categorizes the user based on several indicators, including gender, age, and years of computer experience. The second page asks open-ended questions. The intent of these questions is to collect qualitative data regarding the use of the *Virtual Geology* application. At CSU, San Bernardino, any survey instrument that requires input from human subjects requires prior approval from the Human Subjects committee. To complete this requirement, this author submitted to the committee a copy of the questionnaire, as well as a document that stated the intent of the questionnaire and how it would be implemented. Once approval was granted, the questionnaire was ready for duplication.

**Implementation**

Implementation is the fifth step in this six phase process. The implementation process for *Virtual Geology* involved copying the application to appropriate media, duplicating the questionnaire, and monitoring the usage of the application.

To make the application accessible to the Physical Geology 101 students involved making multiple copies of the completed *Virtual Geology* application. The size of the application (120 MB of data) limited the possibilities for how this application could be distributed. Two possibilities were proposed. First, the application could be installed onto each hard drive of the computers in the Academic Computing and Media self-
The second alternative was making CD-ROM copies of the application, and allowing the students to check out a copy when requested. In discussing this matter with Academic Computing and Media, it was decided to use the CD-ROM solution instead of the hard drive solution. The main reason for this decision was a departmental policy that does not allow discipline-specific applications to be installed in the lab environment. The basis for this policy is the lack of available support for such applications, and the lack of resources to accommodate all possible requests.

This author decided to pursue the possibility of using CD-ROMs for the distribution of Virtual Geology. Academic Computing and Media has computer hardware with the capability to copy data (e.g., the finished Virtual Geology application) to recordable CD-ROM media. This meant that all production of the final distribution copies could be completed on campus. To perform this task, this author purchased blank, recordable CD-ROMs (approximately $10.00 each) and duplicated the final Virtual Geology application to this medium. The advantage to using CD-ROMs (over the hard drive installation) is that the final CD version is read-only and cannot be modified or deleted by the student. The disadvantage to using CD-ROMs is that they are a write-once medium. This means that once the duplication process is started, the medium is used. It cannot be reused, erased, changed, or updated. This validates how important it is to complete a thorough application review during the formative evaluation phase.

Another factor which limited the distribution of Virtual Geology was the "rights" this author had to distribute the final application. These "rights" are part of the software license agreement imposed by Macromedia (the developer of Authorware). This author

106
purchased an educational version of Authorware. The purchase price for this educational version was significantly less than the purchase price for the commercial version ($500.00 compared to $3,500.00). However, by purchasing the educational version, this author lost the right to mass produce Virtual Geology and sell it via commercial avenues (e.g.: computer stores or mail order). Under the conditions imposed by Macromedia, this author can only sell the final product to recover development costs, not to make a profit. At this time, five CD-ROM copies of Virtual Geology are available for check-out in the Academic Computing and Media self-instructional computer lab. If the usage demand increases, additional CD-ROM copies can always be made.

As part of this study, the students who use the Virtual Geology application have been asked to complete a questionnaire. This questionnaire was developed during the formative evaluation phase. To help ensure the validity of the answers, the student was given the questionnaire after he or she returned the CD-ROM to the self-instructional lab assistant. The student was asked to give the completed questionnaire to his or her Physical Geology 101 lab instructor. For this study, the student's use of Virtual Geology was strictly voluntary; no incentive (e.g.: extra credit) was offered. The results from the questionnaire are discussed in the summative evaluation phase.

As part of the implementation phase, this author monitored the use of the Virtual Geology application. This involved assisting the Geological Sciences faculty in advertising to their students the availability of the application, training the student assistants in the self-instructional computer lab in how to assist students who request the
use of the application, and making sure that each student who did use the application received a questionnaire.

To promote Virtual Geology, this author created an advertisement flyer that explained the application and told the students the location of the lab. These flyers were distributed to each student at the beginning of the Winter and Spring quarters, 1996. To further promote Virtual Geology, this author loaned the Geological Sciences faculty a Macintosh computer so they could demonstrate the application to the students. The lab assistants were shown how to use the application. They were also asked to record the names of the students who used the application. From this list, this author sent a second questionnaire to these students. These students were asked to complete the questionnaire, only if they had not done so before. This measure helped to ensure that this study would include as many possible responses.

**Summative Evaluation**

The sixth step in the systems design process is the summative evaluation phase. This phase included reviewing the student responses to the Virtual Geology questionnaire and enhancing the Virtual Geology application, based on the feedback from the student users and the faculty.

The pilot study for Virtual Geology consisted of collecting data during the Winter and Spring quarters of 1996. For these two quarters, the total number of students enrolled for Physical Geology 101 was approximately two-hundred and thirty. In this pilot study, twenty-three students used the Virtual Geology application, representing 10% of the total number of possible student users. Responding to the questionnaire was a
voluntary activity. Of the twenty-three students who used the application, twelve students responded to the questionnaire. These twelve students represent 5.2% of the total number of possible student users. Due to this small sample size, the responses may not represent the actual student population of the Physical Geology 101 class.

The main purpose of this questionnaire was to informally survey the student participants. The desired outcome was to determine the student’s perception and acceptance of the *Virtual Geology* application. Because this was an informal study, specific statistical measures were not implemented. This factor limited the type of statistical analysis that could be performed utilizing the data collected. In a more formal statistical analysis, selecting a “control group” would be required at the onset of the study. In any future statistical study of *Virtual Geology*, the control group could consist of students who would not be given the opportunity to use the computer-assisted application. Using a T-test analysis, the control group’s test scores could be compared to the test scores from the students who did use the application. An analysis of variance (ANOVA) could be used to compare data within a specific variable and to compare data across variables. Given a much larger statistical population, and the use of a control group, these forms of statistical analysis could provide more specific and concrete results regarding the effectiveness of this computer-assisted application.

*Summary of the Open-Ended Questions:*

The *Virtual Geology* questionnaire included seven open-ended questions. Of the twelve students who responded to the questionnaire, ten students (4.3% of the total possible student users) answered the open-ended questions. The intent of the open-ended
questions was to determine the student's reaction to the application and to provide possible validation for the implementation of the visual learning theory. Specifically, this author asked open-ended questions to acquire qualitative feedback. Listed below is each question and a summary of the responses.

Question One:  *How did you choose to navigate (move around) through this program? For example, did you complete an entire section, or just certain parts?*

Response Summary: Six of the ten students indicated that they navigated through the program by completing an entire section. Three other students chose to look at just individual modules within a section. The remaining student used an entirely different navigational approach. This student responded that she first took the quiz, then went through the entire section, and then took the quiz again. In her own words, "It was very helpful!"

Question Two: *This program has been developed based on a visual learning theory. This means that a strong attempt was made to explain concepts and terms by use of pictures. In your own words, please tell how successful (or not) this theory was implemented.*

Response Summary: All respondents felt that the use of the imagery was successful. However, two of the students indicated that they would have liked to have seen even more visual examples.

Question Three: *Were you aware as you were using the program that the pictures were used to supplement the written material?*

Response Summary: Of the ten responses, all students indicated that they were aware that the pictures were used to supplement the written material.

Question Four: *Based on your own feelings about how you learn, did this visual approach help you to better understand the material presented?*

Response Summary: All ten students indicated that the visual approach assisted them in understanding the material presented. One student responded that, "The program was so helpful, because I am a visual learner." Another student
responded, "In Physical Geology, there are a lot of terms and definitions, it is helpful to see the pictures of what they mean."

Question Five:  *In your own words, please explain what you liked about the program.*

Response Summary: Six students responded that the visual images were helpful in understanding the material presented. Two students felt that using the application helped them prepare for the lab assignments. One student indicated that she liked the, "Simple ways of explaining definitions, without complicated jargon." Another student indicated that she liked, "How it broke everything down into sections and categories. It takes you step-by-step so you don't get confused."

Question Six:  *In your own words, please explain what you did not like about the program.*

Response Summary: Two students did not respond to this question. Of the remaining eight students, four felt that each quiz should have included more questions. One of these four students elaborated on this response. She said, "Three questions were not enough for review on material that took one hour to go through." One student responded that the application should be available during the lab session. Another student indicated that she would have liked the opportunity to learn more about any one subject, and that there should be an option to do so in the program. One student again requested a CD-ROM that covered the lecture portion of the class. The remaining student felt that there were not enough examples and the program took too long to load. In his words, "It was no substitute for the work in the laboratory."

Question Seven:  *Please provide suggestions as to how this program can be improved.*

Response Summary: Three students did not respond to this question. Of the remaining seven students, four students again indicated that the quizzes should be longer. One student indicated that there, "Could have been more on relative dating methods." Another student felt the application should be "more comprehensive." The one student again requested a CD-ROM that covered the lecture portion of the class.
**Final Conclusions:**

The responses to the first question validate the need for a high level of learner-control. From these responses, it is evident that the *Virtual Geology* hypermedia interface provided the learners with a variety of ways to navigate through the application.

Based on the responses to questions two, three, and four (related to the implementation of the visual learning theory and the use of imagery), the overall response was positive. The students commented on the quality of the pictures, and how viewing the pictures, in combination with the text, assisted them in the learning process. These responses support the overall premise of this study: when a text-based learning environment is enhanced through the use of pictures, students better understand the material presented.

In response to question five, the students again indicated their approval of the application. The three application elements that received the most comments were the quality of the images, the amount of learner-control, and the quiz function.

When asked what they did not like about the application (question six), the majority of the students indicated that each quiz should have been longer in length. This expansion can be accomplished through further application development. One student commented on the slowness of the application. In general, the access speed of information from a CD-ROM depends upon two factors: 1) the equipment used to make the CD-ROM, and 2) the CD-ROM drive used to access the information. Typically, the access speed from a CD-ROM drive is two-to-three times slower than access from a hard drive. Because the *Virtual Geology* application is very large in size, this too can affect the
performance. Solving the access speed problem would require: 1) a CD-ROM duplicator that will allow for a faster format, 2) a faster CD-ROM drive to access the information, and 3) a reduction in the size of the application. Unfortunately, all three of these factors will remain constant in the CSU, San Bernardino environment for some time.

In question seven, the students were asked to provide suggestions for how the program could be improved. Most students again indicated that the quizzes should be longer in length. Some also indicated that they would have liked the program to be even more comprehensive. To improve both factors would require extensive further program development.

**Statistical Analysis**

The *Virtual Geology* questionnaire included eight quantifiable questions. The purpose of these questions was to determine the statistical composition of the sample group. This author also wanted to determine if any significant comparison factors existed between the responses to certain questions. All twelve students responded to these quantifiable questions. Because this small sample size may not represent the actual student population of the Physical Geology 101 class, it will be taken into consideration in the analysis of the results.

Each question is briefly described below, followed by a statistical summary of the responses. These results are self-explanatory. Following the descriptive data are the comparison tables. Within these tables, a comparison of various factors has been made. While conclusions from these comparisons have been drawn, it is imperative to take into
consideration the size of the study group. Again, these conclusions may not be representative of the actual student population.

**Statistical Composition**

Table 1  
*Age Range*

<table>
<thead>
<tr>
<th>Range</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>17-25</td>
<td>5</td>
</tr>
<tr>
<td>26-30</td>
<td>4</td>
</tr>
<tr>
<td>31-40</td>
<td>1</td>
</tr>
<tr>
<td>41-50</td>
<td>1</td>
</tr>
<tr>
<td>51-60</td>
<td>1</td>
</tr>
<tr>
<td>60+</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2  
*Gender*

<table>
<thead>
<tr>
<th>Gender</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>6</td>
</tr>
<tr>
<td>Male</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 3  
*Academic Major*

<table>
<thead>
<tr>
<th>Group</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business and Public Administration</td>
<td>0</td>
</tr>
<tr>
<td>Education</td>
<td>4</td>
</tr>
<tr>
<td>Humanities</td>
<td>2</td>
</tr>
<tr>
<td>Natural Sciences</td>
<td>5</td>
</tr>
<tr>
<td>Social and Behavioral Sciences</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 4  Previous Computer Experience

(n = 12)

<table>
<thead>
<tr>
<th>Level</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginner</td>
<td>1</td>
</tr>
<tr>
<td>Intermediate</td>
<td>6</td>
</tr>
<tr>
<td>Advanced</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 5  Type of Computer Experience

(n = 12)

<table>
<thead>
<tr>
<th>Level</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macintosh</td>
<td>3</td>
</tr>
<tr>
<td>PC (IBM or Clone)</td>
<td>4</td>
</tr>
<tr>
<td>Both</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 6  Sections of the Program Used

(n = 12)

<table>
<thead>
<tr>
<th>Section</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topographic Maps</td>
<td>4</td>
</tr>
<tr>
<td>Rock-forming Minerals</td>
<td>9</td>
</tr>
<tr>
<td>Igneous Rocks</td>
<td>9</td>
</tr>
<tr>
<td>Sedimentary Rocks</td>
<td>8</td>
</tr>
<tr>
<td>Metamorphic Rocks</td>
<td>5</td>
</tr>
<tr>
<td>Relative Dating</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 7  Time of Day the Program was Used

(n = 12)

<table>
<thead>
<tr>
<th>Time</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.M. Before Noon</td>
<td>4</td>
</tr>
<tr>
<td>P.M. After Noon</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 8  Length of Time the Program was Used

(n = 12)

<table>
<thead>
<tr>
<th>Length</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Minutes or Less</td>
<td>3</td>
</tr>
<tr>
<td>Between 30 Minutes and 60 minutes</td>
<td>7</td>
</tr>
<tr>
<td>Over 60 minutes</td>
<td>2</td>
</tr>
</tbody>
</table>

Comparison Factors

The tables shown below compare various statistical factors from the Virtual Geology questionnaire. These comparisons have been made to determine if any significant factors exist between the responses to certain questions. For Tables 9, 10, and 11, CSU, San Bernardino enrollment statistics, published by the Office of Institutional Research, have been used as comparison figures. These enrollment statistics are representative of CSU, San Bernardino's student population as of Fall, 1995.
Table 9  *Age Range by Gender*

(n = 12)

<table>
<thead>
<tr>
<th>Range</th>
<th>Female</th>
<th>% of Female Sample</th>
<th>Male</th>
<th>% of Male Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>17-25</td>
<td>2</td>
<td>33.3</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>26-30</td>
<td>3</td>
<td>50</td>
<td>1</td>
<td>16.7</td>
</tr>
<tr>
<td>31-40</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>16.7</td>
</tr>
<tr>
<td>41-50</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>16.7</td>
</tr>
<tr>
<td>51-60</td>
<td>1</td>
<td>16.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>60+</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Conclusion:** The results displayed in Table 9 indicate a young student population within the Physical Geology 101 class. Compared to the overall campus demographics, this author can only reliably compare students within the youngest age range (18-25). All other age groupings in the campus statistics are considerably different than the age groups defined in this study. According to the campus statistics, females within the age range 18-25 account for 58% of the total female population (Office of Institutional Research, 1996). Within this study, the female student population for this age range accounted for only 33.3% of the sample group’s female population, considerably less than the comparable campus female population. The campus statistic for the male student population in the age range 18-25 is 59% of the total number of males (Office of Institutional Research, 1996). Within this study, the males in this age range accounted for 50% of the male population, 9% less than the comparable campus male population.
Table 10  Age Range by Major

<table>
<thead>
<tr>
<th>Group</th>
<th>17-25</th>
<th>26-30</th>
<th>31-40</th>
<th>41-50</th>
<th>51-60</th>
<th>60+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business and Public Administration</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Education</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Humanities</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Natural Sciences</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Social and Behavioral Sciences</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Conclusion: These figures indicate that the majority of the younger students chose either Education or Natural Sciences as their major. The results from older students (ages 31 to 60) are split between Education, Humanities, and Social and Behavioral Sciences. According to CSU, San Bernardino statistics, the School of Natural Sciences has the youngest student population with approximately 64% of the students between the ages of 18 and 24 (Office of Institutional Research, 1996). School of Education has the highest older student population. Approximately 74% of the School of Education student population is between the ages 34 to 54 (Office of Institutional Research, 1996).

Table 11  Major by Gender

<table>
<thead>
<tr>
<th>Group</th>
<th>Female</th>
<th>%</th>
<th>Male</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business and Public Administration</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Education</td>
<td>3</td>
<td>50</td>
<td>1</td>
<td>16.7</td>
</tr>
<tr>
<td>Humanities</td>
<td>2</td>
<td>33.3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Natural Sciences</td>
<td>1</td>
<td>16.7</td>
<td>4</td>
<td>66.6</td>
</tr>
<tr>
<td>Social and Behavioral Sciences</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>16.7</td>
</tr>
</tbody>
</table>
Conclusion: These figures indicate that the majority of the female students are Education majors. The majority of the male students are Natural Science majors. When compared to CSU, San Bernardino statistics, the above numbers do not coincide with the campus student population. According to the CSU, San Bernardino statistics, the Schools of Humanities, Natural Sciences, and Social and Behavioral Sciences all have higher percentages of female students. Only by a small percentage do males outnumber females in the Schools of Business (49.3% female) and Education (44.7% female) (Office of Institutional Research, 1996). The reason for this discrepancy may be the small sample size.

Table 12  

<table>
<thead>
<tr>
<th>Level</th>
<th>Female</th>
<th>%</th>
<th>Male</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beginner</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>16.7</td>
</tr>
<tr>
<td>Intermediate</td>
<td>3</td>
<td>50</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>Advanced</td>
<td>3</td>
<td>50</td>
<td>2</td>
<td>33.3</td>
</tr>
</tbody>
</table>

Conclusion: The figures in Table 9 indicate a fairly even gender distribution. They also indicate that the majority of the students (eleven of the twelve) had significant computer experience prior to using the Virtual Geology application. This is a subjective measure. The questionnaire does not indicate how much experience constitutes a beginner, intermediate, or advanced user. If the subjectivity factor is disregarded, these figures could indicate that the Virtual Geology application may only appeal to students with at least some computer experience. This possibility should be taken into consideration in the
course of future academic quarters, and will be addressed in the final section of this chapter.

Table 13  

<table>
<thead>
<tr>
<th>Range</th>
<th>Female</th>
<th>%</th>
<th>Male</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 minutes or less</td>
<td>3</td>
<td>60</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Between 30 minutes and 60 minutes</td>
<td>2</td>
<td>33.3</td>
<td>5</td>
<td>83.3</td>
</tr>
<tr>
<td>Over 60 minutes</td>
<td>1</td>
<td>16.7</td>
<td>1</td>
<td>16.7</td>
</tr>
</tbody>
</table>

**Conclusion:** These figures indicate that the female students spent the least amount of time using the application. The majority of the male students (five of the six male students) spent at least thirty minutes using the application. From the data presented, it is difficult to draw a conclusive reason for this difference. Based on a response from one female student, it could simply mean that students did not allow for enough time to use the application effectively. In this case, the female student indicated that she “ran out of time” while using the application before class. She indicated that she was only able to spend less than thirty minutes using the application. Fortunately, the hypermedia interface allows for this type of constraint. Students with a limited amount of time can choose to look at just the individual modules which they need assistance with.

*Enhancing the Virtual Geology Application:*

The students who answered the open-ended questions provided valuable, qualitative feedback. Their requests for lengthier quizzes and more examples indicate serious attempts to understand the material presented. This author recognizes that the suggestions made describe possible improvements for the *Virtual Geology* application.
Improving these two areas (longer quizzes and more visual examples) would require this author to devote significant additional time and financial resources to the development of this application. In consideration of the amount of time and resources already invested in the development of this application, this author is unable to implement these requests within the time constraints of this project. However, given the importance of this feedback, a recommendation for how these requests can be implemented will be made in the final section of this chapter.

During the summative evaluation phase, two enhancements were made to the Virtual Geology application. These enhancements include the option for the students to hear the names of the different minerals verbally spoken and a video clip that demonstrates the Physical Geology principle of "cleavage." Both enhancements are within the "Rock-forming Mineral" section. Both enhancements were scheduled to be part of the original release of Virtual Geology (Winter, 1996), but were excluded due to time constraints.

The addition of the verbal element required the completion of several steps. First, each mineral name was recorded by using a Macintosh computer, a standard Macintosh microphone, and voice digitizing software called SoundEdit 16. Once each specimen name was recorded, it was saved to a digital file. These files were individually imported into the Virtual Geology application. This verbal enhancement was added to the "Alphabetical Look-up" section. Beginning Fall quarter, 1996, Physical Geology students will have the option of using this module with the "voice over" or without verbal names. This flexibility allows students to make a choice that best meets their individual learning needs.
The second enhancement to the application was the addition of a video clip that demonstrates one of the physical characteristics commonly used to identify minerals. The characteristic of "cleavage" is one of the more difficult concepts for students to understand. In Physical Geology terms, a mineral has a cleavage if it has a "direction of weakness that when broken produces a smooth plane that reflects light" (Foster, 1971, p. 9). In the initial planning stages for this application, the Physical Geology faculty felt that a video clip that demonstrated the principle of "cleavage" would assist the students in understanding this concept. To produce this video clip, this author used a video camera to film a demonstration of "cleavage:" A Physical Geology faculty member used a rubber mallet to break a large piece of the mineral Halite. Once broken, the resulting smaller pieces of Halite (showing cubic cleavage) were then held up and shown to the camera.

To include this video clip in the Virtual Geology application, this author first had to transfer, or digitize, the video footage into a format that the computer would recognize. First, the video camera had to be connected to a Macintosh computer that was capable of capturing video. This initial step was completed by linking the "video out" port on the video camera and the "video in" port on the Macintosh 7100 AV computer. Once connected, this author used the Macintosh software application Premiere to view and transfer the desired video footage into a digital format. The digitized video clip was then imported into Virtual Geology. Beginning Fall quarter, 1996, Physical Geology students will have the option of viewing this video clip when they select the term "cleavage" from within the "Terms and Definitions" module.
In all situations of learning, it is important to offer the students a variety of materials, resources, and choices. Well designed computer-assisted instruction can provide the students with all three factors. The six step system design approach is a strategic mechanism for the development of computer-assisted instruction. As this study shows, each step builds upon the previous step. No step can be eliminated or passed over. However, the process does not, and should not, end with the completion of the summative evaluation phase. For Virtual Geology, the results from the summative evaluation suggested several possibilities for further enhancement and curriculum integration. Each area will be explored further in the following sections.

**Enhancements**

The responses to the open-ended questions on the Virtual Geology questionnaire proposed several ideas for enhancing this application. These ideas were discussed at length in the summative evaluation section of this chapter. Each suggested enhancement was valid and worthy of consideration. Given enough time, resources, and support, these proposed enhancements could be implemented into the application. In consideration of future enhancements, the modular design of Virtual Geology will prove to be extremely advantageous for such expansion. Additions, changes, and even deletions can be made to each section or module without affecting the overall design or function of the application. This modular structure encourages interesting and collaborative enhancements that could
involve faculty and students from several different disciplines. Proposed collaborative arrangements are discussed below.

*Virtual Geology* is a prime example of a collaborative development effort. As an M.A. student in the School of Education, Instructional Technology program, this author collaborated with the Geological Sciences faculty and students to design and develop this application. The development of the photographic and illustrative elements is also an example of such collaborative efforts. The efforts put forth by the first reader of this project show even another type of collaborative development. These types of partnerships could easily continue in the future. As a graduation requirement, each student in the School of Education M.A. program must complete a project such as this. Future M.A. candidates could partner with Physical Geology to develop the three sections that were not included in the original release of this application. M.A. candidates could also work to add additional pictures, illustrations, sounds, and movies that would elevate this application from hypermedia to multimedia (e.g.: the use of various forms of media to create a multisensory information environment). While the main focus of this study examined the effect of illustrated text, a change from hypermedia to multimedia would give a future M.A. candidate a different research focus.

Other disciplines on the CSU, San Bernardino campus could also be involved in this type of collaborative development. For example, Art and Graphic Design students could be recruited to develop necessary illustrations, or to photograph additional mineral and rock specimens. Psychology students could use the *Virtual Geology* application to perform a detailed statistical analysis on the implications of hypermedia learning. Business
and Computer Science students could change the format of this application, making it accessible through the Internet. Future enhancements should not be restricted to the interest of CSU, San Bernardino faculty and students. For example, faculty and students from other universities could also be involved. This type of collaborative effort would not only foster application enhancement, but multi-site implementation.

**Curriculum Integration**

When integrating computer-assisted instruction into any curriculum there are several different implementation methods to consider. Three generalized methods include informal integration, motivated integration, and formal integration. For this pilot study, an informal method of integration was used. During the Winter and Spring quarters, 1996, the Geological Sciences faculty taught this course in a traditional manner. The students attended the classroom lecture and then the hands-on lab. For this pilot study, the use of *Virtual Geology* was not a required student activity, and therefore not an integrated part of the curriculum. Instead, this application was promoted as an additional study aid. Students who used the *Virtual Geology* application did so on a voluntary basis. The only incentive offered was the possibility of enhanced learning. This method of informal integration showed limited usage of the application. Only 10% of the total enrollment for these two quarters chose to utilize the application. Lack of previous computer experience may be the cause of this limited usage. While this factor is important to consider, it is not restricted to just the informal integration method. As such, it is important to discuss the other two methods of integration before looking at possible solutions to this issue.
Motivated Integration

Motivated integration is a mediated step between informal and formal integration. This method calls for only a moderate change in how Physical Geology 101 is taught. As for the classroom lecture and hands-on lab, traditional methods could still be employed. However, within this form of integration, an incentive plan would be used to encourage more students to use the Virtual Geology application. For example, students would be able to earn extra grade points in return for their use of the Virtual Geology application. Worksheets could be developed that would require the students to use the application in order to identify correct answers. While the use of Virtual Geology would still be voluntary, motivated integration could possibly encourage more students to use this application.

Formal Integration

Formal integration is a step beyond motivated integration, and in many ways, it is in direct opposition to the informal integration method. Formal integration would require a paradigm shift in how Physical Geology 101 is taught. The use of the Virtual Geology application would no longer be a voluntary student activity. Instead, the use of this application would become an integrated element of this course. In this approach, students would be required to purchase their own copy of Virtual Geology, either through an increase in the lab fee, or through the bookstore. This is suggested because it would make the application the student’s personal, valued property, much like a textbook. The completion of pre-lecture/lab computer assignments would be required that fully utilize this application. These assignments would then become the basis for the lecture and
hands-on lab discussions. Since the basic instruction would be completed through the use of the application, the Geological Sciences faculty would then be able to expand on this previously explored material. The faculty would be able to provide further explanations and engage the students in more in-depth discussions. Through formal integration, the role of the faculty would shift from being "sole providers" of the information to "facilitators" of the learning process. For this type of shift to take place, it is imperative that the students complete the pre-lecture/lab assignments. To insure this, a pre-test could be given at the start of each session. The course grading scale would reflect the importance of these pre-test scores, influencing the students to complete these assignments.

Overcoming the Lack of Experience Factor

Making a modification in how Virtual Geology is integrated into the curriculum could increase the number of student users. As earlier addressed, the lack of previous computer experience may have limited the students' use of this application. On the Virtual Geology questionnaire, students were asked to indicate their level of computer experience (beginning, intermediate, or advanced). The data collected from this one question strongly suggests that previous computer experience may be an important factor in who chooses to use this application. Eleven of the twelve students indicated at least an intermediate level of computer experience. While the Virtual Geology application was designed for students with all levels of computer experience, students with little or no computer experience may be too uncomfortable, or even afraid, to venture into this
unknown environment. Fortunately, the university setting provides different options for overcoming this possible factor.

The first option would include a guided tour of the self-instructional computer labs, complete with a hands-on demonstration of the *Virtual Geology* application. A demonstration would raise the student's comfort level by reducing that initial anxiety brought on by trying something for the first time. A guided tour would familiarize all Physical Geology students with the location of the self-instructional labs and the available student computing resources. Regardless of the method of integration employed (informal, motivated, or formal), this type of initial assistance could prove to be a motivating factor. A guided tour may possibly influence all students (regardless of computer experience) to use this application again.

Another possibility for overcoming the lack of previous computer experience would include the formation of peer study groups. At the start of each quarter, the Physical Geology students would be asked to rate their level of computer experience. Using this information, the Physical Geology faculty could choose peer groups that would include a varied level of computer experience (from beginner to advanced). During the first two weeks of each quarter, the peer groups would use formal class time to meet and assist each other with using this application. Making the initial use of this application a "group" project would reduce the stress associated with a lone attempt. Through this group experience, students without previous computer experience would realize that they could use this application without fear or embarrassment.
Concluding Remarks

As this study has shown, hypermedia is a powerful tool that can be used to create and deliver computer-assisted curriculum materials. Through the use of hypermedia, the elements of text, sound, images, and video can be combined into one integrated instructional tool. Such integrated instructional tools can change the process of education from that of a passive student activity, to a learning environment that encourages the involvement of every student.

Hypermedia, by itself, is only a set of development tools and programming instructions. There are several factors that contribute to the development of quality in hypermedia materials. These factors include a strong learning theory basis, the use of a comprehensive structured development process, the quality of the supporting media elements, and a curriculum integration scheme that effectively promotes the intended learning outcome.

The first part of this study explored a variety of learning theories. While each theory is different and unique, the theories reviewed do overlap in several instances. The visual learning theory and Gagné’s conditions of learning were selected as the educational foundation for the Virtual Geology application. Both theories recognize the importance of visual information, as well as instructional design.

For this study, the visual learning theory provided a conceptual framework for how text and pictures are initially processed, how this information is encoded into long-term memory, and then how it is later recalled. This learning theory provided thorough guidance on the most effective ways to incorporate text and pictures into a computer-
assisted application. Also included in the discussion of this theory was the support for the different types of images and diagrams included in the *Virtual Geology* application. As such, decorative images were not included in this application.

Gagné has identified five categories of learning. Portions of two of his five categories, intellectual skills and verbal skills, were incorporated into the *Virtual Geology* application. The intellectual skills category describes how the student uses different mechanisms to learn and use verbal information. From discriminations to problem solving, activities for acquiring and practicing these different skills were integrated into the *Virtual Geology* application. The second category, verbal information, was also applied to the *Virtual Geology* application. Within this category, students learn how to process basic verbal terminology related to a specific topic. Using *Virtual Geology*, students are presented with a completely new set of terms and concepts associated with Physical Geology. Through the use of contiguous text and pictures, students are given the opportunity to form mental models that can serve as intellectual representations for later recall of complex content.

The second factor that contributes to the quality of computer-assisted instructional materials is the use of a comprehensive structured development model. For this study, a phased “systems approach” was used. Within each of the six phases, an outline of tasks was generated. All tasks were completed within each phase before work began on the next phase. This systematic process resulted in a computer-assisted application that is both comprehensive in content and structure, and effective in presenting the material to the students.
One of the most beneficial outcomes of the six phase development process was the modular design of the *Virtual Geology* application. The modular design allows each student to select his/her own learning path. It also allows each student to work independently of the other students, and of the instructor. Another positive outcome includes the use of a standardized method for presenting a vast amount of information. Because the *Virtual Geology* application was produced through an intense collaborative effort involving this author and the Geological Sciences faculty, the information presented to the students is clearly defined, complete, and accurate.

The third factor that contributes to the effectiveness of computer-assisted instructional materials is the quality of the supporting media elements. For the *Virtual Geology* application, these media elements include everything from the carefully selected backgrounds to the meticulous design and development of each illustration and picture. Of the four contributing factors, the design and development of the various media elements was by far the most time consuming process. This is understandable, as these elements form the core of the *Virtual Geology* application.

In support of the visual learning theory, the goal of this project was to augment the text-based lab manual with an illustration or picture for each key concept. This author worked collaboratively with the Geological Sciences faculty to complete this task. For the concepts that required an illustration, this author researched the topic and developed a draft diagram. The program illustrator completed the task by finalizing each illustration. The photographic elements were developed through a similar process.
Once the development process was completed, the illustrations and the photographs were integrated into the application. Through further collaboration with Geological Sciences, this author was also able to add verbal pronunciations and a video segment to the "Rock-forming Minerals" section.

Choosing an appropriate curriculum integration scheme is the fourth factor that contributes to the quality of computer-assisted instructional materials. It is important to choose a curriculum integration scheme that effectively promotes the intended learning outcome. In this study, three generalized schemes, informal integration, motivated integration, and formal integration, were discussed. Each scheme offers a scenario for how the computer-assisted application could be used as part of the student’s learning experience.

With the informal integration scheme, the computer-assisted application is used as a study aid, used outside of formal class time. The motivated integration scheme elevates the importance of the computer-assisted application by rewarding those students who use the application. The third scheme, formal integration, recommends full use of the computer-assisted application. In this case, the application would be used to provide the students with basic instruction. As stated earlier, formal integration changes the role of the faculty from being the “sole provider” of the information to that of a “facilitator” of the learning process. For this study, an informal integration scheme was used. However, in future implementations, this author recommends that either the motivated or the formal integration scheme be used as a way to further promote the use of this application.
Visual learning is one of several modalities by which individuals perceive, encode, store, and later retrieve learned information. The theory of visual learning indicates that the integration of text and images is crucial to the learning process, and the study of visual learning can contribute to the design of effective learning materials. To facilitate the visual learning process, computer-assisted instructional materials must be geared toward assisting in this complex mental process. Hypermedia, with its capability to present both text and pictures in a non-linear fashion, is a very appropriate tool for this task.

This author tested the implementation of the visual learning theory, through the use of hypermedia, by developing a computer-assisted instructional application. This application is currently being used by the CSU, San Bernardino Physical Geology students.

Serving as an interactive physical geology manual, this computer-assisted application was designed to link key words to intricate illustrations and high-quality color images. This application utilizes these key words and graphics to build cognitive associations (mental models) for the learner.

The overall results from the Virtual Geology questionnaire indicate that this application was successful in promoting the projected learning outcomes. These outcomes included: 1) the recall of correct information from short-term memory; 2) the integration of the factual components into a conceptual knowledge base; and 3) the application of the knowledge base to future situations relating to geological sciences and the physical world that surrounds us.
APPENDIX A:
VIRTUAL GEOLOGY QUESTIONNAIRE

Virtual Geology

Completion of this questionnaire is voluntary. Any information you provide will be held in strict confidence. At no time will your name be reported along with your responses. The goal of this questionnaire is to provide feedback to the researcher that will result in improvement of this program, as well as rationale for the learning theory that was implemented.

Name (optional):

Age Range:  ( ) 17-25  ( ) 26-30  ( ) 31-40  ( ) 41-50  ( ) 51-60  ( ) 60+

Gender:  ( ) Female  ( ) Male

Major:  ( ) Business and Public Administration
       ( ) Education
       ( ) Humanities
       ( ) Natural Sciences
       ( ) Social and Behavioral Sciences

Previous Computer Experience:  ( ) Beginner  ( ) Intermediate  ( ) Advanced

Type of Computer Experience:  ( ) Macintosh  ( ) PC (IBM or Clone)

What sections of the program did you use (check all that apply):
   ( ) Topographic Maps  ( ) Rock-forming Minerals
   ( ) Igneous Rocks   ( ) Sedimentary Rocks
   ( ) Metamorphic Rocks  ( ) Relative Dating

What time of day did you use the program:  ( ) a.m. - before noon  ( ) p.m. afternoon

How much time did you spend using the program?  ( ) 30 minutes or less
       ( ) between 30 minutes and one hour  ( ) over one hour
How did you choose to navigate (move around) through this program? For example, did you complete an entire section, or look at just certain parts?

This program has been developed based on a visual learning theory. This means that a strong attempt was made to explain concepts and terms by use of pictures. In your own words, please tell how successful (or not) this theory was implemented.

Were you aware as you were using the program that pictures were used to supplement the written material?

Based on your own feelings about how you learn, did this visual approach help you to better understand the material presented?

In your own words, please explain what you liked about the program.

In your own words, please explain what you did not like about the program.

Please provide suggestions as to how this program can be improved:
## APPENDIX B:
### HARDWARE AND SOFTWARE
#### PRODUCT LIST

<table>
<thead>
<tr>
<th>Product:</th>
<th>Purpose:</th>
<th>Company:</th>
</tr>
</thead>
<tbody>
<tr>
<td>ColorOne flatbed scanner</td>
<td>Scanner capable of digitizing printed</td>
<td>Apple Computer, Inc.</td>
</tr>
<tr>
<td>(hardware)</td>
<td>photographs or diagrams.</td>
<td>20525 Mariani Avenue</td>
</tr>
<tr>
<td>Macintosh 7100 AV computer</td>
<td>Computer with the capability to digitize both audio and video (AV) formats.</td>
<td>Apple Computer, Inc.</td>
</tr>
<tr>
<td>(hardware)</td>
<td></td>
<td>20525 Mariani Avenue</td>
</tr>
<tr>
<td>Nikon 4500 slide and film scanner</td>
<td>Scanner capable of digitizing processed (not printed) film or slides.</td>
<td>Nikon, Inc.</td>
</tr>
<tr>
<td>(hardware)</td>
<td></td>
<td>1300 Walt Whitman Road</td>
</tr>
<tr>
<td>Authorware, version 2.0 (software)</td>
<td>Hypermedia development application based on flowcharts and icons.</td>
<td>Macromedia, Inc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>600 Townsend Street</td>
</tr>
<tr>
<td>ClarisWorks, version 4.0 (software)</td>
<td>Integrated application that includes tools for word processing, spreadsheets, databases, painting, and drawing.</td>
<td>Claris Corporation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P.O. Box 58168</td>
</tr>
<tr>
<td>HyperCard, version 2.0 (software)</td>
<td>Hypermedia development application based on cards and stacks.</td>
<td>Apple Computer, Inc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20525 Mariani Avenue</td>
</tr>
<tr>
<td>HyperStudio, version 3.0 (software)</td>
<td>Hypermedia development application based on cards and stacks.</td>
<td>Roger Wagner Publishing, Inc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1050 Pioneer Way, # P</td>
</tr>
<tr>
<td></td>
<td></td>
<td>El Cajon, CA 92020</td>
</tr>
<tr>
<td><strong>Product:</strong></td>
<td><strong>Purpose:</strong></td>
<td><strong>Company:</strong></td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Photoshop, version 3.0 (software)</td>
<td>Color graphics program used for image-processing (with Nikon Scanner) or photo retouching.</td>
<td>Adobe Systems, Inc. 1585 Charleston Road P.O. Box 7900 Mt. View, CA 94038-7900</td>
</tr>
<tr>
<td>Ofoto, version 1.0 (software)</td>
<td>Software used with the ColorOne flatbed scanner.</td>
<td>Apple Computer, Inc. 20525 Mariani Avenue Cupertino, CA 95014</td>
</tr>
<tr>
<td>SoundEdit 16 (software)</td>
<td>Software that converts audio information (analog data) to a digital format.</td>
<td>Macromedia, Inc. 600 Townsend Street San Francisco, CA 94103</td>
</tr>
<tr>
<td>SuperCard, version 2.0 (software)</td>
<td>Hypermedia development application based on cards and stacks.</td>
<td>Allegiant Technologies, Inc. 6496 Weathers Place, #100 San Diego, CA 92121</td>
</tr>
</tbody>
</table>
REFERENCES


