Alessi, S. M., & Trollip, S. R. (2001) *Multimedia for Learning: Methods and Development* (3rd ed.). Boston, MA: Allyn & Bacon, Inc.
ISBN-13: 9780205276912

Multimedia for Learning

Methods and Development

THIRD EDITION

Stephen M. Alessi
The University of Iowa

Stanley R. Trollip
Capella University

Allyn and Bacon
Boston ■ London ■ Toronto ■ Sydney ■ Tokyo ■ Singapore

To our parents

Series Editor: Arnis Burvikovs
Editorial Assistant: Patrice Mailloux
Senior Marketing Manager: Brad Parkins
Production Editor: Christopher H. Rawlings
Editorial-Production Service: Omegatype Typography, Inc.
Composition and Prepress Buyer: Linda Cox
Manufacturing Buyer: Julie McNeill
Electronic Compositon: Omegatype Typography, Inc.

A Pearson Education Company
160 Gould Street
Needham Heights, Massachusetts 02494

Internet: www.ablongman.com

Previous editions were published under the title *Computer-Based Instruction: Methods and Development,* copyright © 1991, 1985.

Library of Congress Cataloging-in-Publication Data
Alessi, Stephen M.
Multimedia for learning : methods and development / Stephen M. Alessi, Stanley R. Trollip.—3rd ed.
p. cm.
Rev. ed. of: Computer-based instruction. 2nd ed. c1991.
Includes bibliographical references and index.
ISBN 0-205-27691-1 (alk. paper)
1. Computer-assisted instruction. 2. Education—Data processing. 3. Interactive video. 4. Artificial intelligence—Educational applications. I. Trollip, Stanley R., 1947– II. Alessi, Stephen M., 1951– Computer-based instruction. III. Title.

LB1028.5 .A358 2001
371.33'4—dc21 00-060603

Printed in the United States of America

20 19 18 17 16 09

CHAPTER 2

Learning Principles and Approaches

Introduction

Developing effective materials (in any medium) that facilitate learning requires an understanding and appreciation of the principles underlying how people learn. Just as engineering is the application of basic principles from physics and chemistry, and as medicine is the application of basic principles of biology, instruction is the application of basic principles of learning. As you design educational software, you should always be thinking about the principles of learning, and assessing whether your software reflects and is compatible with them.

However, no universal agreement exists on how learning occurs. How psychologists have viewed the principles of learning has changed significantly throughout the 20th century. Today many educators are strong proponents of particular approaches, whereas others take a more eclectic approach, which comprises a combination of principles from different theories. In the middle of the 20th century, learning theory was dominated by the principles of behavioral psychology, exemplified by the work of B. F. Skinner (1938, 1969, 1974), which maintains that learning should be described as changes in the observable behavior of a learner made as a function of events in the environment.

In the 1970s, the behavioral paradigm began to be expanded by the ideas of cognitive psychology, which maintains that a complete explanation of human learning also requires recourse to nonobservable constructs, such as memory and motivation. However, not all psychologists and educators abandoned behavioral principles in favor of cognitive principles; indeed, many ardent behaviorists continued to insist that behavioral theory and approaches were best. A few more ardent cognitive psychologists sought to throw out all the tenets of behavioral psychology and begin with a completely new approach. However, the vast majority of psychologists and educators simply added the new cognitive learning principles to those of behavioral psychology.

In the 1980s, a new learning paradigm, constructivism, began to influence education and instructional design. Constructivist philosophy counters objectivist or positivist philosophy. Objectivist philosophy maintains that the world follows real and consistent rules and that proper learning consists of being able to understand and apply those rules to function in the real world. In contrast, constructivist philosophy (in its extreme form) maintains that only an individual's interpretation of the world matters and that everyone constructs their own view of reality. Constructivist educators maintain that older paradigms (behavioral and cognitivist) treated the learner as a bucket into which knowledge about the world was poured by teachers, books, and other instructional media. In contrast, constructivism views learners as active creators of knowledge, who learn by observing, manipulating, and interpreting the world around them.

As was the case in the shift from behavioral to cognitive paradigms, neither behavioral nor cognitive principles were abandoned in favor of constructivist principles. In fact, the variety of opinions about how people learn is now greater than ever before. Many ardent behaviorists maintain that both cognitivists and constructivists are "unscientific" because they deal with ideas that cannot really be observed and measured. Many cognitivists, or those who combined elements of both behavioral and cognitive learning psychology, oppose the constructivist approach, criticizing it for being more philosophy than science, for being unprovable, or for not adding anything new to the debate. Radical constructivists argue that educational institutions are in grave danger if they continue to function based on behavioral or cognitive principles and that our educational systems must be redesigned along constructivist principles. In reality, those who cling to a single approach (behavioral, cognitive, or constructivist) are relatively few, and the majority of learning psychologists, educators, and instructional designers prefer to merge various principles of behavioral, cognitive, and constructivist paradigms into one integrated approach.

The following sections describe the primary principles of these three learning paradigms. Understanding these principles is essential to understanding the ongoing debate in the field of education about the best instructional approaches. It is also essential to the debate among instructional designers about how multimedia should be used to design effective educational materials. Following the description of the principles, more about this lively debate and how it is influencing the design and use of educational multimedia is discussed.

Behavioral Psychology Principles

Behavioral psychology began at the turn of the twentieth century, primarily with the work of Edward Thorndike (1913) and Ivan Pavlov (1927). Pavlov's research concerned classical conditioning. He noted that an animal's basic instinctual responses to natural stimuli (for example, a dog salivating when it smells food) could be linked to artificial stimuli. For example, Pavlov would ring a bell each time he gave food to a dog, and he observed that eventually the dog would salivate at the ringing of the bell, even when no food was present. The unconditional (or natural) stimulus of food elicits the unconditional (also natural) response of salivating. The neutral stimulus of a bell does not normally elicit salivation, but after training it becomes a *conditioned* stimulus, and salivation in response to a conditional stimulus is a conditioned response. Salivation, or other natural behaviors, may be both a natural or unconditioned response to food and a learned or conditioned response, such as to a bell. The basic principle of classical conditioning is that repeatedly pairing a neutral stimulus with a natural stimulus (one that elicits a natural response) causes the neutral stimulus also to elicit the response. The implication is that humans learn many behaviors because of their pairing with basic human needs and responses, such as the need for food, sleep, reproduction, and the like.

Also around the turn of the twentieth century, Thorndike conducted research that is now termed operant conditioning: the use of rewards and punishments to modify behavior. This work was refined and greatly popularized by B. F. Skinner and gave rise to the behavioral school of psychology and learning, the dominant paradigm of learning psychology for much of the 20th century. Extending the work of Thorndike, Skinner demonstrated a small number of basic behavioral rules. (1) Behavior that is followed by positive environmental effects (known as positive reinforcement, or reward) increases in frequency. (2) Behavior that is followed by the withdrawal of negative environmental effects (known as negative reinforcement) also increases in frequency. (3) Behavior that is followed by a negative environmental effect (punishment) decreases in frequency. (4) When behavior that was previously increased in frequency through reinforcement is no longer reinforced, it decreases in frequency (known as extinction).

Skinner went on to demonstrate that particular patterns of reinforcement or punishment result in different rates of learning and degrees of retention of what is learned. One of the most important such principles is the principle of intermittent reinforcement. Behavior that is *always* rewarded increases rapidly in frequency, but after the reward ceases the behavior also extinguishes rapidly. In contrast, behavior that is rewarded *intermittently* increases in frequency more slowly, but is more long lasting or resistant to extinction.

In addition to his research on operant conditioning, Skinner became a strong proponent of a behavioral philosophy, maintaining that the psychology of learning should *restrict* itself to the study of observable behaviors and environmental events. He maintained that discussion or research of nonobservable constructs, such as memory, beliefs, or the mind, were detrimental to the study of learning. He also maintained that strict behavioral psychology principles could be used to improve education dramatically (Skinner, 1968) and society in general (Skinner, 1948). Many psychologists followed his lead and, through much of the twentieth century, the study of learning in the United States was dominated by behaviorism.

Behavioral psychology and learning theory led to developments, such as programmed textbooks, classrooms based on token economies (Ayllon & Azrin, 1968), and, less directly, to mastery learning programs (Block, 1980) and programs of individually prescribed instruction or IPI (Glaser, 1977). These in turn led to systems of computer-managed instruction (Baker, 1978) and today's Integrated Learning Systems (Shore & Johnson, 1992).

The field of instructional design grew rapidly due to the formulation of Instructional Systems Design or ISD (O'Neil, 1979a; 1979b). Instructional System Design was an approach to developing instruction, primarily in industry and the military, which attempted to meet the need of developing a large amount of effective instruction that would promote mastery learning. It was designed primarily for teaching adult skills and knowledge rather than for K–12 education.

ISD procedures are largely based on behavioral psychology. Their emphasis is on specifying behavioral objectives (statements of things the learner will be able to *do* at the end of instruction), analyzing learning tasks and activities and teaching to specific levels of learner performance. The ISD model begins at the curriculum level with analysis of content, definition of overall objectives, delineation of sequences and subsequences of the curriculum. It proceeds with the selection of instructional methods and media, designing individual lessons to enhance learner mastery of the objectives, developing delivery systems for the individual lessons, and ends with evaluation of the lessons and the entire instructional system. Evaluation in ISD emphasizes measurement of observable target behaviors.

ISD models are still widely used, especially in industry and military educational environments. However, ISD models are also widely criticized. Earlier criticisms were based on the complexity of ISD models and that they provide direction at the more global curriculum level but less at the lesson (micro) level. More recent criticism has centered on the behavioral emphasis of ISD models: that they ignore important unobservable aspects of learning (such as thinking, reflection, memory, and motivation); that although they are good for teaching intended learning outcomes, they often overlook or even ignore valuable unintended outcomes; and that they place too much emphasis on the instructor and instructional materials and too little on the learner. These criticisms are valid, though sometimes exaggerated.

Another current criticism is that Instructional Design (ID) and Instructional Systems Design (ISD) are essentially the same and that ID has an equally strong behavioral emphasis. However, ISD can be considered one type of ID model and instructional design models were developed during the 1980s and 1990s that include cognitive and constructivist elements (Reigeluth, 1999).

Cognitive Psychology Principles

The dominance of behaviorism began to wane in the last third of the twentieth century, and cognitive psychology began to overtake it during the 1970s as the dominant paradigm of learning psychology. Cognitive psychology takes its name from the word *cognition,* which means the process of knowing. Cognitive psychology places emphasis on unobservable constructs, such as the mind, memory, attitudes, motivation, thinking, reflection, and other presumed internal processes.

Of the different schools of cognitive learning psychology, perhaps the most dominant is based on an information-processing approach. Growing in part out of work in computer science on artificial intelligence, information-processing theories attempt to describe how information in the world enters through our senses, becomes stored in memory, is retained or forgotten, and is used. They claim that information is stored initially in short-term memory and must be used or organized to become stored more permanently in long-term memory. Most information-processing approaches include the notion that memory and thinking have a limited capacity, which accounts for failures in attention and in memory. Also included is the notion of an executive control, which coordinates the learner's perception, memory, processing, and application of information. Underlying the information-processing approach is the assumption that the senses and the brain follow complex but very systematic laws and that we can facilitate learning to the extent we can determine those laws.

Another school or theory of cognitive psychology is semantic networks. This theory attempts to parallel how biologists view the connections of the human brain. Each brain cell is connected to many others, in a vast spiderweb or network. Similarly, pieces of information, or *nodes,* are hypothesized to be connected to many other pieces of information in a vast *semantic* network of interconnecting information and meaning. These nodes are connected by relationships, or *links,* which can be characterized by similarity, opposition, cause and effect, or time. The brain contains billions of cells with many billions of connections. According to semantic network theory, our knowledge consists of nodes connected in countless ways. Remembering, thinking, acting, problem solving, and other cognitive activities consist of information (nodes) being activated via relationships or connections to other information (links to other nodes) that in turn activates other information. This spreading activation of billions of nodes via links accounts for cognitive activity.

In a semantic network such as the brain, learning may be represented by removing or adding links between nodes or by creating or changing nodes. Thus, underlying semantic network theory is the assumption that prior knowledge (the current state of a semantic network of nodes and links) is critical and that learning is the incorporation of new knowledge into the network of prior knowledge. Incorporation of new knowledge may occur by assimilation (new information is modified to fit into the framework of existing knowledge and beliefs), or accommodation (existing knowledge is modified to accept the new), or a little of both.

For example, new knowledge may be so surprising that people interpret the new information in a way that is congruous with existing knowledge or beliefs (assimilation). But this new knowledge may become so clear and incontrovertible that eventually existing knowledge must also change (accommodation) to remain acceptable in light of the new knowledge. Assimilation and accommodation often account for difficulties in learning and remembering new information.

Closely related to semantic network theories is Schema Theory, which began with the ideas of Sir Frederick Bartlett (1932). Schemas (or schemata) are highly organized collections of information and their relationships, similar to a semantic network. Schema Theory postulates that our existing knowledge comprises collections of such schemas. For example, we have a schema for *home* and the things, people, and activities that take place there. We have a similar yet different schema for *restaurant* and the different things, people, and activities that occur there. Similarly we have schemas for all our knowledge, including transportation, play, politics, religion, and so on. Learning takes place when schemas are modified to incorporate new knowledge. New knowledge may be modified to be assimilated, or schemas may be modified to accommodate the new knowledge, or some of both may occur.

The discussion of the major methodologies of interactive multimedia and, later, the design of multimedia programs are primarily guided by several issues central to cognitive psychology. The areas of cognitive theory that are most important to multimedia design are those relating to perception and attention, encoding of information, memory, comprehension, active learning, motivation, locus of control, mental models, metacognition, transfer of learning, and individual differences (Anderson, 1980; 1981; Anderson, 1977; Berger, Pezdek, & Banks, 1986; Bower & Hilgard, 1981; Gagné, Yekovich, & Yekovich, 1993; Kozma, 1987). These categories reflect most of what is important when designing and evaluating interactive multimedia. Following is a summary of each.

Perception and Attention

Learning begins with attention to and perception of information in the learner's environment. Perception and attention are neither automatic or easy. Perception is constantly strained by many competing stimuli. Attention may falter or be attracted to different stimuli than the desired ones. Three main principles are relevant to perception and attention. (1) Information (visual or aural) must be easy to receive. (2) The position (spatial or temporal) of information affects our attention to and perception of it. (3) Differences and changes attract and maintain attention.

Ease of perception is the basis for many screen design considerations, such as the size and fonts used for text, the use of color, the size and level of detail used in pictures, and the volume and clarity of audio. The choice of mode also affects ease of perception. For example, reception of music is easier in aural form (listening to it) than visual form (reading sheet music). Another consideration for ease of perception is repeatability. Information that changes through time (such as speech, animation, or motion video) is more likely to be retained if learners can repeat it. A final factor concerning ease of perception is pace. Information presented too quickly or too slowly increases the difficulty of both attention and perception.

Position of information is primarily spatial for visual information and temporal for aural information. Placement of images on a computer or video screen determines whether we notice them and think about them. Designers generally place more important visual information near the center of a screen and secondary information, such as directions, toward the edges. The timing of aural elements (such as commands or narration) is important to their perception and effect. Providing the ability to repeat aural elements is a way of improving learning by increasing accessibility.

Differences and changes attract and maintain attention and underlie the use of various text sizes, colors, and fonts; changing backgrounds and music; and dynamic techniques, such as animation and motion video. Attention is drawn to change, whether it is dynamic (such as animation) or periodic (such as background color changing from one lesson segment to another).

For perception of lesson elements to occur, the attention of learners must be not only initially attracted but *maintained* throughout the lesson. In addition to the lesson characteristics just discussed, attention is affected and maintained by many characteristics of the learners themselves, including the level of involvement in the lesson, personal interest in the topic, prior knowledge about the content, the difficulty of the lesson for them, and the novelty or familiarity of the information. Throughout the chapters that follow, recommendations for display design, methods of interaction, and motivational considerations are guided by the principles of perception and attention in learning.

Encoding

Once the learner attends to and perceives stimuli, cognitive psychologists believe that it must be *encoded.* This means it must be transformed into a format that can be stored in the brain. Encoding depends on a number of factors, including the format of the information in the environment (e.g., whether verbal information is English or Spanish), the medium of the information (e.g., whether it is visual or aural), and the interrelationships of different information elements.

Of particular relevance to interactive multimedia is the principle of *dual coding* (Clark & Paivio, 1991) and the *multimedia effect* (Mayer, 1997; Mayer, Steinhoff, Bower, & Mars, 1995). Dual coding theory suggests that learning is enhanced when complementary information codes are received simultaneously. The best example of this is the combination of complementary visual material and narration, as when a weather reporter on the nightly news describes the warm and cold fronts while you view a weather map. Visual and aural information can conflict, for example, listening to a person speak while viewing text with different wording. Learning is best facilitated by a combination of complementary visual and auditory information.

Mayer has used the term *multimedia effect* to indicate the learning benefits of combining different visual and aural information. It follows from dual coding theory and applies directly to interactive multimedia. Multimedia programs can include text, speech, drawings, photographs, music, animations, and video with or without sound. Some combinations complement one another and facilitate learning, whereas others conflict and impede learning. Closely related to this and to dual coding theory is the notion that learning is enhanced through the use of multiple symbol systems (e.g., Dickson, 1985). An example of multiple symbol systems is an algebraic equation that can be displayed either as a string of text (e.g., $y = 3x + 7$) or as a graph depicting that relationship visually. Instructional materials tend to be more effective when knowledge is depicted in a number of ways using different symbol systems.

Memory

Having perceived and encoded information we must also be able to retrieve it and use it at a later time. Although the information storage and retrieval capacity of humans is immense, ensuring that the important information can be recalled is not trivial. Instructional techniques for efficient storage of knowledge are essential, especially when faced with new and large bodies of information, such as the vocabulary of a new language.

Two principles underlie almost all methods of enhancing memory—the principle of organization and the principle of repetition (Fleming & Levie, 1978). The principle of organization says that information is remembered better and longer when it is organized, when organization is imposed upon it, or when the learner is made aware of the organization. The organization principle is demonstrated by an example from foreign-language vocabulary learning. Remembering twenty arbitrary words (selected at random from a dictionary) is much more difficult than remembering the names of twenty *foods,* which is relatively easier. This example shows the advantage of natural organization inherent in the content to be learned.

Imposing organization, although sometimes artificial, also is effective. Children are often taught to remember the names of the five Great Lakes by the mnemonic HOMES, reflecting the first letters of the lakes, Huron, Ontario, Michigan, Erie, and Superior. Mnemonics, analogies, songs, and aphorisms (e.g., red sky at morning, sailors take warning, red sky at night, sailors delight) are a few of the methods for imposing organization to make new information more memorable.

The principle of repetition claims that the more information is practiced or used, the better and longer it is remembered. The repetition principle is applied in a learner's use of flash cards, a teacher's use of classroom recitation and quizzes, and other examples of repeated exposure to information or practice of skills. It is perhaps the most common of instructional methods and perhaps somewhat overused.

The organization principle, when it can be applied, is more powerful than the repetition principle. Showing a learner the organization of new information or imposing organization upon it often makes recall easy without much practice. But the organization principle is not always appropriate or convenient to use, such as when information has no inherent organization, when a large amount of information must be remembered, when automaticity is required, or when motor or psychomotor skills are being learned. When using organization is inappropriate or impossible, repetition should be used. For situations in which organization is applicable, a combination of both the organization principle and the repetition principle is often best. Learning foreign-language vocabulary is again a good example.

It is important to note that memory is also affected by motivation (to be discussed soon) and by the relevance of the information to the learner. Remembering new information is difficult when information is not relevant or the learner is not motivated. On the other hand, a highly motivated learner presented with relevant information can learn under almost any conditions.

Comprehension

Information we perceive must be interpreted and integrated into our current knowledge of the world. We must not only store and retrieve information, but be able to classify it, apply it, evaluate it, discuss it, manipulate it, teach it to other people, and so on. Comprehension of a word does not mean just being able to state its definition, but also being able to use it appropriately in speech and writing and being able to understand other people when they use the word. Similarly, comprehension of a concept does not mean being able to define it, but being able to make fine discriminations and distinguish examples from nonexamples. And comprehending rules and principles is not just being able to state them, but being able to apply them appropriately.

It is common for instructional materials to place most of their emphasis on remembering information or performing skills with too little on comprehension. For some learning goals or objectives, remembering might be appropriate. In general, however, remembering is just the first step. Being able to apply what is learned outside of the instructional setting depends on the facilitation of comprehension. To consider comprehension in instruction properly, it is convenient to distinguish different types of comprehension and how they are reflected in learners' behaviors. This leads to knowing how to design interactions that facilitate the desired behaviors.

Comprehension of verbal information is often reflected in being able to restate the information in your own words or to explain it to someone else. Comprehension of concepts is reflected in being able to distinguish examples and nonexamples, including difficult discriminations and gray areas. Comprehension of rules and principles is reflected in knowing when they apply and demonstrating correct application. Selection and design of appropriate interactions for a lesson, therefore, can enhance comprehension in contrast to mere recall.

Active Learning

The cognitive approach places an emphasis on active learning because it assumes people learn not only by observing but by doing. This also demonstrates the importance of interactivity in multimedia programs, as interaction not only maintains attention, but helps create and store new knowledge and skills, and facilitates comprehension.

One of the essential features of interactive multimedia, in contrast to more traditional media, is its capacity to require learner actions and act on them. Although multimedia proponents always stress this important aspect, it is the characteristic on which much commercial courseware falls short. Designing interactions that are frequent, relevant, interesting, and have an appropriate level of difficulty, is more difficult than even many experienced developers believe.

Despite rapid advances in computer technology in the last decade, designers are still limited in the modes of action available for interaction between a user and a computer. These modes are primarily keyboard (typing) and mouse-driven interactions (pointing, dragging, drawing). This should be contrasted to communication between people, which includes speaking, listening, arguing, touching, motioning, facial expressions, and the like. Of course, learner activity in a multimedia environment does not *have* to be just between the learner and the computer. Learner activities can be on paper, on a peripheral connected to a computer, or with other people working collaboratively in the multimedia environment. Choosing actions to facilitate learning goals should go beyond human-to-computer interactions and include human-to-human interactions, human-to-computer-to-human interactions (via a network), human-to-paper interactions, and human-to-equipment interactions.

Designing activities that support learning but do not overwhelm people is not easy. Gavora & Hannafin (1995) have suggested a model for designing interaction strategies that takes into consideration (1) whether responses are primarily physical or mental actions, (2) how much mental or physical effort the responses require, (3) whether mental or physical actions are automatic or must be intentional, and (4) the extent to which the actions support the tasks and knowledge to be learned. Designing active learning requires balancing all of these factors.

Motivation

Motivation is essential to learning, but defining what it is and what role it plays leads to disagreement. Several theories of motivation explain how to enhance it. For example, should we design materials that attempt to instill motivation, or should we try to take advantage of the motivations the learner already has? Is motivation the same as "being interested" or "enjoying" something, or is it deeper? Are some kinds of motivation better than others (e.g., praise, money, game techniques, or grades)? Are the same motivational techniques appropriate for all people, or do we need different ones for children versus adults or for males versus females?

Two models for motivation are frequently used in multimedia design. Malone and Lepper (Lepper & Chabay, 1985; Malone, 1981; Malone & Lepper, 1987) propose a theory that intrinsic motivators (those that come from within the person, such as one's personal interests) are more beneficial to learning than extrinsic motivators (those that are applied from outside, such as grades from a teacher). They maintain that four elements enhance intrinsic motivation: challenge, curiosity, control, and fantasy. The more a program includes these four elements, the more successful learning is because people enjoy it more.

The other motivation theory popular in multimedia design is that of Keller (Keller & Suzuki, 1988). Keller also suggests four components (some similar to Malone's) as being essential to motivation, namely: attention, relevance, confidence, and satisfaction. The theory, therefore, is known by the acronym ARCS, or as Keller's ARCS model of motivation design.

Malone's Motivation Theory In his early research on motivation, Malone (1981) suggested three relevant factors: challenge, curiosity, and fantasy. In later work (Malone & Lepper, 1987) he added learner control.

Challenge The most important principle is that the level of challenge should be individualized for and adjusted to the learner. A lesson should not be too easy, but also not too difficult. Setting challenging goals at the start of the lesson is beneficial. Having uncertain outcomes, wherein the learner is not sure if they are attainable, increases challenge. Varying the difficulty of material as learner performance improves maintains challenge throughout the lesson.

Curiosity Malone differentiates between sensory curiosity and cognitive curiosity. Sensory curiosity is aroused by visual or auditory effects that are surprising or attract attention. Cognitive curiosity is aroused by information that conflicts with the learner's existing knowledge or expectation, is contradictory, or is in some way incomplete. These situations encourage the learner to seek new information that remedies the conflict.

Control Three rules are relevant to learner control: contingency, choice, and power. According to the contingency rule, what the lesson does should be clearly a result of the learner's actions and responses. Lessons which give feedback as a function of specific responses or which follow different paths through the content based on learner performance, follow the contingency rule. The choice rule encourages procedures, such as menus and global branching options, that permit the learner to determine sequence or lesson parameters, such as difficulty. The notion of power is that lessons in which learners' actions have "powerful effects" will be very motivating. Such lessons include environments in which the learner creates computer programs or uses computer tools, such as graphics programs.

Fantasy Fantasy situations encourage learners to imagine themselves in imaginary contexts or events using vivid realistic images. Although fantasy is usually associated with games, other methodologies can incorporate it in many ways. Suggesting to learners in a typing lesson that they are taking a test for a high-paying executive secretary position may increase involvement and effort. In an astronomy lesson about the constellations, a fantasy that you are lost at sea and must use knowledge of the stars to return home may be similarly effective. In any lesson, it may be valuable to encourage learners to envision themselves in a situation where they can really use the information they are learning.

Intrinsic versus Extrinsic Motivation Lepper and Malone (Lepper, 1985; Lepper & Chabay, 1985; Malone & Lepper, 1987) have argued that motivators may be either intrinsic or extrinsic. Extrinsic motivators are independent of the instruction, such as paying learners or otherwise offering learners rewards they consider desirable. Lepper's research has provided evidence that extrinsic motivators diminish one's interest in learning because the goal becomes the reward rather than learning. This has been a somewhat controversial claim, however, with researchers arguing both for and against the use of extrinsic motivators (Cameron & Pierce, 1994; 1996; Kohn, 1996; Lepper, Keavney, & Drake, 1996; Ryan & Deci, 1996).

Intrinsic motivators, in contrast, are inherent in the instruction. Put in common terms, instruction is intrinsically motivating if learners consider it to be *fun*. Lepper and his associates suggest several techniques to enhance intrinsic motivation:

- Use game techniques.
- Use embellishments (such as visual techniques) to increase learner intensity of work and attention and to encourage deeper cognitive processing.
- Use exploratory environments.
- Give the learner personal control.
- Challenge the learner.
- Arouse the learner's curiosity.
- Give encouragement, even when errors are made.

Additionally, they point out that techniques for maintaining motivation should be considered at both the macro- and micro-level. The macro-level refers to the instructional strategy level, such as using gaming techniques. The micro-level refers to specific elements of a lesson, such as using graphics and animation. Lastly, they emphasize that motivation techniques must be individualized, because different learners find different topics interesting.

Keller's ARCS Motivation Theory Another set of suggestions for increasing learner motivation comes from the work of Keller (Keller & Suzuki, 1988). Keller's general point of view is that the instructional designer must be proficient at motivation design as well as instructional strategy and content design. Keller indicates four design considerations for creating motivating instruction: attention, relevance, confidence, and satisfaction.

Attention Attention must not only be captured early in the lesson, but be maintained throughout. Curiosity, as in the Malone theory, is one way to do so. Perceptual and content variety also maintain attention.

Relevance Showing learners that what they are learning will be useful to them is the meaning of relevance. The examples just described for encouraging fantasy serve also as examples for showing relevance. A more direct way is for content and examples to be those of interest, or importance, to the learner. In a math lesson, engineering students are more likely to find math problems relevant if they are about engineering problems, whereas education students are more likely to find the problems relevant if they are classroom grading problems.

Confidence Three practices increase confidence: (1) making expectations for learning clear to the learner, (2) providing reasonable opportunities to be successful in the lesson, and (3) giving the learner personal control. These are similar to Malone's notions of providing challenge and learner control.

Satisfaction Several activities increase satisfaction by enabling learners to apply what they have learned in real and useful ways. These include providing positive consequences following progress, giving encouragement during times of difficulty, and being fair. Fairness is accomplished through lesson consistency, through activities in keeping with stated objectives, and through intelligent and consistent evaluation of learner actions.

Motivation in Moderation We are in agreement with these authors on the importance of designing with learner motivation in mind. Motivation is an essential aspect of instruction. A lesson may be perfectly sequenced and worded, yet still fail to teach when learners become bored. Although the recommendations made in the above theories are supported by research, they must still be applied intelligently and in moderation. The designer must keep in mind, for example, that although learner control is motivating, too much control has been demonstrated to impede learning because some learners make poor decisions. Similarly, the designer must not go overboard in encouraging fantasy or providing positive consequences. Instructional design is always a series of compromises, balancing competing factors (such as motivation versus program control) to create effective lessons. We will return to the importance of motivation when we discuss drills and games.

It should be clear from these two approaches that some aspects of motivation are beyond a designer's control (such as what a learner is personally interested in), whereas others are controllable by the designer (such as making relevance clear or setting the proper level of challenge). The multimedia designer should approach the issue of motivation with two objectives in mind: how can one capitalize upon entering motivation, and how can one design the lesson to improve motivation beyond that.

Locus of Control

Locus of control means whether control of sequence, content, methodology, and other instructional factors are determined by the learner, the program (actually the lesson author), or some combination of the two. Although the potential for flexible learner control is an often-claimed advantage of interactive multimedia (Laurillard, 1987), its effects on motivation and learning are complex (Hannafin, 1984; Hannafin & Sullivan, 1995; Hicken, Sullivan, & Klein, 1992; Lawless & Brown, 1997; Milheim & Martin, 1991;

Relan, 1995; Steinberg, 1989; Young, 1996). Substantial evidence shows that some learners (usually the higher achieving ones) benefit from greater learner control whereas others (lower achievers) benefit from less control. Differences have been shown for different ages as well.

Furthermore, learners and programs can control many instructional factors. Some, such as pacing, reviewing, and requesting help, are generally beneficial and used well by most learners. Others, such as selecting instructional strategies, setting difficulty, or deciding when material has been mastered, are often better controlled by the program. Locus of control reflects an important compromise in multimedia design because learners prefer and are motivated by having control; yet, although control is beneficial to some learners, for others it is an impediment. All lessons have a mixture of learner and program control, but the optimal solution may be to give the learner control of *some* factors, generating a good perception of control, whereas in reality only providing partial control.

Mental Models

A mental model refers to a representation in working memory that can be "run" by the learner to understand a system, solve problems, or predict events. One may have a mental model of long division, of how a computer executes loops, or of how electricity flows and operates in a circuit. Many cognitive psychologists consider mental models to be critical components of developing knowledge and expertise (e.g., Frederiksen, White, & Gutwill, 1999).

Learners may develop either correct or incorrect mental models, so facilitating the former is beneficial. However, opinions differ about what a mental model is. Some psychologists say that any internal image is a mental model. Others only regard an internal representation as a mental model if it can be run by the learner, if it has a structure which parallels the real phenomenon, and if it is a short-term as opposed to a long-term mental construct (Jih & Reeves, 1992; Jonassen & Henning, 1999; Mayer, 1992; Seel, 1992; White, 1993).

What seems clear to us is that when learners must understand complex skills or phenomena, the formation and refinement of mental models is a crucial (even if intermediate) component of that learning. Because learners may not develop mental models spontaneously, the question is how designers can assist their formation and proper refinement.

A method suggested to help learners develop good mental models is to provide *conceptual models* (Hagmann, Mayer, & Nenninger, 1998). Whereas a mental model exists in a learner's mind, conceptual models are devices presented by teachers or instructional materials. Computer diagrams, animations, and video presentations have all been suggested as means of providing conceptual models that help develop learners' mental models. This suggests that multimedia technology, with its excellent capacity for animation, diagrams, and the like, has great potential for developing mental models.

Metacognition

Metacognition refers to one's awareness of one's own cognition. Some similar and related concepts are metamemory (awareness of how well one remembers or has remembered something), and metacomprehension (awareness of how well one is understanding something). Researchers believe increasingly that high achievers have good metacognition as well as good cognition. However, evidence also shows that whether one's cognitive abilities are high or low is not related to whether one's metacognitive ability is high or low. Learners can be grouped into four categories: learners high in both cognition and metacognition, learners low in both cognition and metacognition, learners high in cognition and low in metacognition, and learners low in cognition and high in metacognition.

The first category can be defined as good learners and the second as poor learners. But what of the other two? Learners high in cognition and low in metacognition should also be familiar to you. Those are your friends who are always fearful of failing, who consequently overstudy, and who always do well. Learners low in cognition and high in metacognition are those who are having trouble learning and realize it. They try to compensate by seeking help and studying harder. They have half the battle won. Those with the greatest problem are low in both cognition and metacognition, for they are not learning what they study yet they think they are.

It has been suggested that designers and teachers need to pay as much attention to learners' metacognition as to their cognition (Lundberg & Olofsson, 1993; Mayer, 1998; Sternberg, 1998). However, helping learners with metacognition has proved to be elusive. Components suggested for metacognition include general self-awareness (of one's own knowledge and ability levels), reflection (stopping and thinking about what one has been doing and where one is going), and self-assessment (giving oneself tests, mental or actual, to assess if cognition has been good). Techniques have also been suggested for inclusion in multimedia programs. They include reminders to stop and reflect, assistance with self-assessment, working with a partner (collaborative learning) so each person can assist the other's self-awareness, and practice activities to actually develop metacognitive skills (Cates, 1992; Lieberman & Linn, 1991; Osman & Hannafin, 1992; Schraw, 1998; Shin, 1998). Veenman et al. (1997) maintain that metacognitive skills can be taught independently of specific content areas, which suggests that if multimedia programs include features to improve learners' metacognitive skills in one content area, they also improve learning in others.

Transfer of Learning

Learning in a multimedia lesson is often a precursor to applying or using that knowledge in the real world. *Transfer of learning* (Broad & Newstrom, 1992; Clark & Voogel, 1985; Cormier & Hagman, 1987; Detterman & Sternberg, 1993; Gagné, Foster, & Crowley, 1948; Garavaglia, 1996; Greeno, Smith, & Moore, 1993; Sternberg & Frensch, 1993) refers to the extent to which performance in one situation (such as a multimedia lesson) is reflected in another situation (such as working on the job or in a subsequent lesson). For example, learning in a lesson on addition and subtraction is useful in lessons on multiplication and division, assuming the knowledge transfers. Transfer of learning also, and perhaps more commonly, means applying what is learned in an instructional environment to real-world activities, such as being able to fly an aircraft after having used a flight simulator program.

Two different types of transfer have been proposed, *near* transfer and *far* transfer (Clark & Voogel, 1985). Near transfer is applying the learned information or skills in a new environment that is very like the original one. Far transfer is being able to use learned knowledge or skills in very different environments. Different instructional techniques are applicable to each. The theory of identical elements (Gagné, 1954) suggests that near transfer is enhanced by having the elements of the instructional environment (both stimuli and responses) very *similar* to those of the application environment. Far transfer is more likely to be enhanced by building *variation* into the instructional environment so as to facilitate generalizing to other stimuli and responses.

The issue of transfer is an important and difficult one for designers and users of multimedia instruction. The computer's limited modes of interaction, typing and moving the mouse, tend to impede transfer when compared to classroom and on-the-job instruction. Designers must put extra effort into countering those limitations. Multimedia techniques such as simulation, case-based learning, and collaborative learning can all play an important role in facilitating transfer.

Individual Differences

Not all people learn alike or at the same rate. Similarly, some instructional methods are better for some learners than for others. Another claimed advantage of interactive multimedia is its capability to individualize. But just like interactivity, this supposed feature is not often taken advantage of and, even when attempted, is difficult to attain. Most commercial software works the same for all users. Better software adapts to individual learners, capitalizing on their talents, giving extra help where needed, and providing motivators learners can respond to. Because not every lesson works for every learner, matching learners up with appropriate lessons and methodologies is important. That in turn depends on continual assessment of individual differences so that proper matching and other decision making can take place.

Perhaps the most important individual difference is motivation. What is of interest to one learner may be boring to another. Different reinforcements (praise, rewards, grades, free time, money) are effective for different people. Some of the motivational techniques suggested earlier, such as arousing curiosity and using fantasy, work better for some learners than others. The individual nature of motivation entails using a variety of motivational techniques (being cautious not to overdo it with too many), assessing individual learners' response to motivators and modifying them accordingly, and giving learners choices among motivational techniques.

Another individual difference of importance is reading versus listening skills. Providing alternatives of text versus speech for verbal presentations can moderate that difference. This difference may exist due to age and educational background, general ability level, personal preference for reading versus listening, or nationality. Regarding the last, another form of accommodation to individual differences is the provision of alternative languages for either text or voice presentations so learners can read or listen in their native language.

Two individual differences that have attracted a lot of attention among educational researchers are learning style (Kolb, 1985) and cognitive style (Messick, 1994). The early claim of learning and cognitive style research was that matching instructional styles to learners' styles would be beneficial. However, the preponderance of evidence has not proved this to be true. Although evidence supporting the implications of learning and cognitive style theories for instruction is inconsistent (Mitchell, 1994), there is good reason to believe that some commonsense style differences play an important role in learners' use of multimedia, such as a preference for working alone or with others. Recently researchers have become interested in how learning styles and cognitive styles affect learning from hypermedia, suggesting that open-ended hypermedia systems are more successful for some types of learners than others (Chen & Rada, 1996; Chou & Lin, 1998; Dillon & Gabbard, 1998; Fitzgerald & Semrau, 1998; Leader & Klein, 1996; Liu & Reed, 1994).

The Cognitive Influence on Interactive Multimedia Design

Although the field of learning psychology changed drastically in the 1970s and after, the field of instructional design was slower to change. Beginning in the 1970s and especially in the 1980s, most instructional designers, including many who espoused the ISD model, began to take cognitive principles into consideration. In computer-based instruction and interactive multimedia, screen design and presentation strategies increasingly reflected theories of attention and perception, and today designers are increasingly (though probably not sufficiently) incorporating motivation principles. Whereas computer-based instruction in the 1960s and 1970s was very program controlled, modern interactive multimedia programs provide a better mixture of learner and program control. Additionally, instructional strategies and user control are increasingly based on individual needs and differences. Interactions are more frequently designed to foster comprehension and metacognition as well as recall. Although the principle of active learning is equally compatible with behavioral principles, the cognitive approach has put increasing emphasis on active learning and on learners' activities being designed and selected to enhance transfer of learning.

Constructivist Psychology Principles

Just as cognitive learning psychology began replacing the predominant behavioral psychology in the 1970s, constructivist learning psychology is now challenging the currently dominant cognitive approach. Constructivism is also a philosophical view. The objectivist philosophy, or world view, holds that there is an objective world that we perceive more or less accurately through our senses, and that learning is the process of correctly interpreting our senses and responding correctly to objects and events in the objective (real) world. Taking an objectivist world view, instruction or teaching is the process of helping the learner correctly interpret and operate within that real world.

In contrast, constructivism holds that the only reality (or the only one that matters) is our individual interpretation of what we perceive. Constructivist learning theory maintains that knowledge is not received from outside, but that we construct knowledge in our head. There are different schools of constructivist thought. For example, according to social constructivism, learning is inherently social. What we learn is a function of social norms and interpretations, and knowledge is not simply constructed by the individual, but by social groups. Moderate constructivism maintains that there is indeed a real world but that our understanding of it is very individual and changing. More radical constructivism holds that we can never really know the exact nature of the real world, so it is only our interpretations that matter.

The important point for instructional designers is that according to the constructivist viewpoint, learning is a process of people actively constructing knowledge. Traditional instructional methods, such as memorizing, demonstrating, and imitating, are considered incompatible with the notion that learning is a process of construction.

Semour Papert's research with Logo was one of the early examples of applying a constructivist view of the educational use of computers. Papert devised Logo, a programming language that he claimed (Papert, 1980) would help learners better learn mathematics concepts and problem solving than more traditional and direct methods of teaching mathematics and problem solving. In recent years Papert and his colleagues have expanded this approach to the more general notion that people learn most things better through construction of computer programs, computer games, or multimedia compositions than through traditional methods of directly teaching content (Harel & Papert, 1991; Kafai, 1995; Resnick, 1994).

In the early to mid-1990s the constructivist approach to learning spread rapidly in the instructional design and multimedia fields (Anderson, Reder, & Simon, 1996; Cognition and Technology Group at Vanderbilt, 1993; Cooper, 1993; Duffy & Cunningham, 1996; Duffy & Jonassen, 1992; Duffy, Lowyck, & Jonassen, 1993; Lebow, 1993; Simons, 1993; Wilson, 1997). An increasingly common point of view is that education has been much too objectivist, treating learners as empty vessels into which knowledge is poured, whereas education should be viewed as learners actively constructing their own knowledge with teachers being coaches, facilitators, or even partners with learners in the learning process. Proponents of this constructivist approach maintain that designers should be creating educational environments that facilitate the construction of knowledge. The following principles or suggestions are typically promoted as ways to accomplish that goal:

- Emphasize learning rather than teaching.
- Emphasize the actions and thinking of learners rather than of teachers.
- Emphasize active learning.
- Use discovery or guided discovery approaches.
- Encourage learner construction of information and projects.
- Have a foundation in situated cognition and its associated notion of anchored instruction.
- Use cooperative or collaborative learning activities.
- Use purposeful or authentic learning activities.
- Emphasize learner choice and negotiation of goals, strategies, and evaluation methods.
- Encourage personal autonomy on the part of learners.
- Support learner reflection.
- Support learner ownership of learning and activities.
- Encourage learners to accept and reflect on the complexity of the real world.
- Use authentic tasks and activities that are personally relevant to learners.

Learning versus Teaching

The constructivist approach puts its emphasis on the active process of learning and deemphasizes teaching activities and instructional methods. Thus, presentation of information is downplayed whereas learner activity is stressed. For example, teacher (or computer) questions are discouraged and learner questions are encouraged (e.g., Jonassen, 1988).

Discovery Learning

Constructivism emphasizes the learner exploring, experimenting, doing research, asking questions, and seeking answers. In contrast to pure discovery environments of the 1950s and 1960s, current constructivist thinking emphasizes guided or even structured discovery environments with learners and teachers as partners in the research experience (e.g., Reigeluth, 1996).

Construction

Although the term constructivism implies that construction is the central emphasis of the constructivist approach, often it is not. Yet some constructivist learning environments are designed with learner construction in mind, such as construction of multimedia programs, construction of simulations or expert systems, construction of essays or newspapers, or construction of video stories. The process of construction entails learners setting or negotiating a goal, making plans, doing research, creating materials, evaluating them, and revising. Papert and his associates refer to their instructional approach as Construc*tion*ism rather than Construc*tiv*ism, reflecting their emphasis on learners' actual construction of learning artifacts (Harel & Papert, 1991).

Situated Learning and Anchored Instruction

One of the more substantial aspects of constructivist thinking is a basis in situated learning and the implied use of the anchored instruction approach (Moore et al., 1994). Situated learning is the theory that learning always occurs in some context, and the context in turn significantly affects learning. Learning is often contextualized, meaning knowledge or skills learned in a particular context are easily repeated by learners as long as they are in *that* context, but are inaccessible outside of that context. Knowledge inaccessible outside of the original learning context is referred to as *inert knowledge* (Renkl, Mandl, & Gruber, 1996). The main implication of situated learning theory is that properly designing the situation in which learning takes place enhances transfer to other settings.

The anchored instruction approach, although not a necessary result of situated learning theory, is often attributed to it. Anchored instruction is the notion that a learning environment should be embedded in a context that is like the real world, with real world imagery, goals, problems, and activities. For example, the anchored instruction approach suggests that mathematics should not be learned in an abstract math class, but in an environment such as running a business, where mathematics is a necessary part of a real-world activity. Learners see the goals as real ones (like the goals people have in real jobs), the problems as real problems they encounter in life, and the activities as meaningful and worth doing.

Cooperative and Collaborative Learning

Another substantial aspect of constructivist thinking is an emphasis on cooperative and collaborative learning (Slavin, 1990). There has been considerable research demonstrating the advantages of collaborative learning (e.g., Flynn, 1992; Hooper, Temiyakarn, & Williams, 1993; Hooper & Hannafin, 1991; Johnson, Johnson, & Stanne, 1986; Johnson

& Johnson, 1996; Klein & Pridemore, 1992; McInerney, McInerney, & Marsh, 1997; Qin, Johnson, & Johnson, 1995; Rojas-Drummond, Hernández, Vélez, & Villagrán, 1998; Susman, 1998; Wizer, 1995; Yueh & Alessi, 1988).

Although many educators use *cooperative* and *collaborative* as interchangeable terms, it is useful to distinguish between them. The more general term, *cooperative,* means learners are helping each other rather than hindering, competing, or ignoring one another. They may be working on individual projects (such as term papers or science experiments), but the environment supports learners helping and teaching one another. *Collaborative* learning goes a bit further, suggesting environments in which learners work on a *shared* project or goal, such as a group of learners working on a newspaper or rebuilding a car engine. Disagreement about this distinction exists, however. Some educators stress that even cooperative learning does not mean simply "learners working together" but learners working on joint goals. Although learners working together is not necessarily cooperative or collaborative (they may simply be sharing resources or may even be competing), *collaborative* suggests joint goals whereas *cooperative* more generally implies similar goals and helping one another.

Both cooperative and collaborative environments have several claimed advantages. Interactivity is enhanced and more multisensory (including conversations between learners and other activities, not just typing and reading); participants play the roles of both learners and teachers; motivation can be enhanced; social skills are fostered; and metacognitive skills may be improved.

Some potential disadvantages are also ascribed to cooperative and collaborative environments, notably that they benefit some learners more than others (Mevarech, 1993). Other possible problems include classroom behavior management, fair grading practices, ownership of the materials created, and optimal grouping of learners. This last issue is an interesting one. Should learners with equal abilities or similar interests be combined in groups, or ones with different abilities and interests? Although the jury is not in, we favor creating goals and groups in which *all* members have the opportunity to be good at *some* activities and need help with others. For example, if a group of learners is creating a class newspaper, we should try to group together a learner who is a good writer, but knows little about photography, with one who is good at photography, but a poorer writer. The goal is for all learners to have the opportunity to help others as well as be helped when they need it.

The issue of cooperative or collaborative learning is an important one for interactive multimedia because historically the field has emphasized individualized instruction. In the early days of computer-based instruction, an often-stated advantage was individualizing instruction and adapting instructional software to each individual. However, with the exception of pacing (learners being able to study materials at the rate they wish and for as long as they wish), educational software has not lived up to the promise of individualization and adaptation. In more recent years the advantages of cooperation and collaboration have been demonstrated, and they entail more attainable goals. However, even though many designers voice support for collaborative environments, few instructional multimedia programs do much to facilitate collaboration. Indeed, desktop computers themselves do not facilitate collaboration very well. However, with the increasing availability of the World Wide Web and growing emphasis on "GroupWare" (software applications that are designed to facilitate teamwork), this may change. At this time, few commercial programs for learning are designed to facilitate collaboration.

Autonomy, Choice, and Negotiation

In keeping with the emphasis on learning rather than instruction and on learners rather than teachers, the constructivist approach suggests that learners should be given choices and the opportunity to be more autonomous in their actions. Rather than instructors deciding the goals and activities of an educational environment, learners and instructors should negotiate and jointly decide the goals and activities. This has several benefits: making goals and activities more meaningful to learners, giving learners a sense of ownership of what is done, increasing motivation, making learners and instructors partners instead of adversaries, and increasing learners planning and metacognitive skills.

Reflection and Strategic Thinking

Following from the last point, the constructivist approach stresses that people should be lifelong learners. An educational environment should foster learning not only of content, such as math or reading, but of learning how to learn (Lieberman & Linn, 1991). Learners should be given frequent opportunities to reflect on and discuss what they have been doing, their success or failure, and what they will do next (e.g., Lin & Lehman, 1999). Learners should have opportunities for strategic thinking, that is, planning how they can achieve learning goals and what they can do when problems are encountered. Once again, these are metacognitive skills, and being a good learner includes exercising both cognitive skills and metacognitive ones.

Reflecting the Complexity of the World

A criticism that constructivist educators aim at traditional and current educational environments is that the knowledge and skills taught are too simplified. Thus, it is claimed, they are not useful in the real world, because learners recognize them as such and are not highly motivated. Transfer to other environments also suffers. Better educational environments should be designed with information, problems, and multiple solution approaches, such as those people encounter in their real jobs and lives (Savery & Duffy, 1995). An interesting and complex issue, however, is just how much of the real world's complexity should be reflected in a learning environment. This issue is discussed in the chapter on simulations along with realism, fidelity, and complexity.

The Constructivist Influence on Interactive Multimedia Design

The constructivist viewpoint has broad implications for traditional and new methods of interactive multimedia. Proponents of the constructivist viewpoint believe that some traditional methodologies, such as tutorial and drill instruction, which they classify as objectivist or instructivist, are poor for developing lifelong learners. They also maintain that much of what is taught with traditional methods produces inert knowledge (Renkl et al., 1996), which is not easily applied in new situations. In other words, traditional methods produce knowledge that does not transfer well. In contrast, constructivists suggest that methodologies such as hypermedia, simulation, virtual reality, and open-ended learning environments are of more benefit to learners, allowing them to explore information freely, apply their own learning styles, and use software as a resource rather than as a teacher. More importantly, constructivists support the use of computer-based tools (in contrast to lessons) with which learners can design and construct their own knowledge (Jonassen, 2000).

Activities such as writing compositions, building simulations and games, and creating movies can be done using software tools, and constructivist educators believe these result in more useful knowledge and skills. They also emphasize using computers for communication, such as e-mail for communication between learners at a distance, Internet chat rooms and video conferencing, and file sharing for group research and project work. Recent advances in the Internet and the World Wide Web for communicating and sharing information are considered more appropriate uses of technology than tutorials or drills by constructivist educators. Computer-mediated communication (CMC) (Romiszowski & Ravitz, 1997) deals primarily with such communicative uses. Some proponents of CMC go so far as to suggest that we should view teaching as a *conversation* rather than as instruction. The former is more two-way, participatory, negotiable, and variable in nature, whereas the latter is more one way and predefined, with instructors speaking and learners listening.

The Constructivist–Objectivist Debate

In the 1990s interest in constructivist approaches surged and there was a rapid growth in the number of educators favoring them. A significant number of those educators believe that we must engage in radical reform of the traditional education systems (the school restructuring movement) and that both technology and constructivist principles should be the basis for school reform. But such proponents have primarily been among researchers and academics concerned with K–12 education. Smaller numbers of actual K–12 teachers and few of those concerned with adult education and training have joined the ranks of staunch constructivist proponents.

The surge of interest among educators resulted in a number of effects. One was that many educators attempted to implement constructivist approaches, with varying amounts of success. The other was a backlash from educators on the other end of the continuum, who maintained that extreme constructivist principles do not work well for many learners, are inefficient, are unproved, and in many cases are little different than cognitive principles (Dick, 1991; Merrill, 1991). The debate has raged for several years now. Although some people at both ends of the continuum have moderated their positions in the light of both argument and research, others have moved to further extremes. Educational researchers and theorists range from the so-called radical constructivist at one end of the continuum to extremely traditional objectivists at the other. However, most educators, especially practicing teachers, are in the middle. Below we discuss our own views on the ongoing debate and what we believe are the implications for educational computing and multimedia.

Criticisms of Behaviorism

A strict behavioral approach, paying attention only to observable learner behaviors and ways to influence them, is not appropriate for multimedia design. Decades of learning research have demonstrated that classical and operant conditioning principles do not predict all learning outcomes. Theories of motivation, memory, transfer, and the like have promoted instructional methods that behavioral techniques would not, and many of these methods have been successful in improving both achievement and affect. We believe the strict Instructional Systems Design (ISD) method that grew out of the behavioral approach resulted in much instructional software that was dry, unmotivating, and difficult to apply in new situations. The outcomes of education and training must include more than just learner achievement. They must include learner satisfaction, self-worth, creativity, and social values. Programmed instruction and ISD-generated training programs often do not emphasize those values. In tomorrow's world, people must be adaptive and lifelong learners, must have the confidence necessary to change with their environment, and must be able to work collaboratively with others. These goals and values were marginally recognized by behavioral approaches to education, which later cognitive and constructivist approaches understandably emphasized.

Having said that, principles from behavioral learning theory are used and should be used in multimedia design. Despite the claims of some constructivist theorists, behaviorism has always emphasized active learning. Learners in a behaviorally designed learning environment or using behaviorally designed materials are almost always actively responding. Their actions are admittedly more reactive than proactive, typically answering questions and solving problems given by the instructor, but they are active. Behavioral principles such as positive reinforcement, corrective feedback, and spaced practice are appropriate in interactive multimedia design, and we will return to them when making design suggestions in future chapters.

Criticisms of Cognitivism

Although many psychologists would like to say that the cognitive approach replaced or supplanted the behavioral approach to learning, we believe it was more of a merger. Although we place ourselves in the cognitive school of learning psychology, we recognize its incompleteness. The cognitive approach, with its increased emphasis on the internal processes of learners, has strayed a bit too far from the importance of active learning. Although cognitively oriented educators voice the importance of interaction in multimedia, statements have not always been transformed into practice. Much educational software created during the era of cognitive dominance has been sadly lacking in learner activity and much too dominated by reading, watching, and listening. The cognitive approach has undervalued the powerful principles of reinforcement. And, although cognitive educators spoke of collaboration, communication, and transfer long before constructivist educators, they did not do a very good job of translating such principles into practice in the learning environments they created.

Criticisms of Objectivism or Instructivism

Objectivism or *instructivism* are terms often used by constructivist educators to define what they consider the opposite end of the continuum from themselves. Few educators say they are objectivist or instructivist whereas many are willing to define themselves as cognitivist or constructivist. These terms represent a straw dog created by constructivist proponents. They claim an objectivist or instructivist believes in pouring knowledge into learners' heads, that the approach is antithetical to collaboration, self-autonomy, active learning, or transfer of learning to the real world. However, *no* educators claim they believe education is pouring knowledge into learner heads or that they are against collaboration or active learning.

Indeed, a sizable number of educators (classifying themselves as behavioral, cognitive, or a combination) believe strongly in the importance of efficient and effective learning environments that stress mastery of primarily behavioral objectives. Though these educators speak of collaborative and active learning, they do not always apply it well, instead emphasizing shorter-term learner outcomes. Such an attitude is especially common in industry and military training where cost-effectiveness is critical and where mastery is necessary to avoid the dangerous consequences of errors in hazardous work environments.

Perhaps the reason that constructivists wish to combine cognitivism and behaviorism into a single entity (called either *objectivism* or *instructivism*) is because people always feel comfortable with a two-ended continuum. The current world of educational philosophies is really a triangle, with behaviorism, cognitivism, and constructivism at the vertices. Most educators are somewhere in the *middle* of that triangle.

Criticisms of Constructivism

Constructivists, as we claim in the previous section, have created a straw dog of objectivism, incorporating into it all the negatively weighted words in education and claiming all the positively weighted words for themselves. This is somewhat disrespectful of the vast majority of educators who take a much more integrated approach to education and instruction. Almost all educators believe in concepts like autonomy, cooperation, lifelong learning, active learning, personal relevance, transfer, meaningful learning, authentic activities, and communication, even if they are difficult to implement in every educational environment and activity. We consider it inappropriate for constructivists to claim that these things are representative of only their approach.

Many constructivists believe that instructional methodologies such as tutorial and drill are inappropriate. We disagree. A complete and flexible educational environment includes a combination of media including people, books, computers, and others. The computer software components should include tutorials, drills, hypermedia, Web-based communications and other methods, depending on the subject matter, the learners, the available resources, and the time constraints.

A radical constructivist approach contains inherent contradictions. For example, some proponents of the constructivist view believe that learners should have control over their learning, which includes not only what they learn but how they learn it (content and strategy). Other constructivists claim that computer drill-and-practice programs should *never* be used. The question then is, what if the learner *wants* a drill? What if a corporate executive is going on a business trip to Paris next month, is taking an intensive course on business French, and now wants a drill to learn as much French vocabulary as possible in the short time remaining? Would a constructivist tell that person, "No, you must practice French vocabulary in the authentic context of real conversations?" And if one did say that, is one *giving* the learner personal autonomy or *removing* it? This does not just concern drill-and-practice activities. In general, the constructivist approach encourages learners to have autonomy, and yet the approach supports certain kinds of learning activities and environments. Reconciling these views (emphasis on autonomy while favoring particular learning strategies) is difficult; a more integrated cognitive approach deals with them more consistently.

Some educators interpret constructivism as an educational philosophy rather than a model or approach to designing educational environments. Others educators regard it as a theory of how people learn, but not necessarily a theory of teaching or creating educational environments. Others see it as an approach to education and for creating learning environments. We fall into the middle category. We believe that people do in large part learn constructively. Young children certainly learn language by imitating, experimenting, and discovering. Primitive humans, before the evolution of language, probably learned everything in this way, even during their adult lives. But children learn language rather slowly and primitive humans took thousands of years to reach the first stages of civilization. Learning by these methods is slow. With the evolution of language and eventually the written word, the pace of human development multiplied a thousand-fold. Even though people *learn* constructively, that does not mean that we cannot *facilitate* learning in many other ways. The rapid development of civilization since the evolution of language and literacy is evidence we should not depend solely on constructivist environments for the efficient facilitation of learning.

A significant segment of the school-restructuring movement believes in restructuring the traditional educational system in light of the constructivist approach. They claim the current system is a failure and should be replaced through revolution rather than evolution. We disagree. The traditional educational system has been successful for many people, though admittedly not all. Educational systems should, in light of history, be based on a combination of behavioral, cognitive, and constructivist principles. In particular, they should incorporate appropriate constructivist methods at a *micro*-level, that is, constructivist lessons, labs, activities, and interaction types, but avoid totally constructivist education systems. The design for an entire elementary school curriculum should not be based on constructivist principles, though it could include them in many individual language, math, and other lessons. Growing research evidence indicates that constructivist methods work better only for learners with well-developed metacognitive skills. Some evidence also indicates that constructivist techniques are very time consuming. In short, constructivist techniques are good for some types of learning, some situations, and some learners, but not all.

Implications for the Use of Computers and Multimedia

The general debate about educational philosophies and approaches has been paralleled in discussions of proper uses of computers, multimedia, and the Internet in education and training. As discussed above, some constructivist proponents are adamantly opposed to using computers for tutorials, drills, and achievement testing. Other educators are opposed to what they consider discovery learning approaches, which they feel proved to be a failure in past decades. In business and industry training environments, some constructivist methods such as interactive hypermedia are viewed as inefficient and ineffective, whereas others, such as electronic performance support systems, are considered useful and in keeping with modern business practices like just-in-time manufacturing.

Well-known educational technology leaders at the constructivist corner of the triangle include Jonassen (1991), Duffy and Cunningham (1996), and Schank (Schank & Cleary, 1995). They contend that appropriate uses of technology should stress constructivist practice. More moderate constructivist approaches are suggested by Hannafin

(Hannafin, Hall, Land, & Hill, 1994), Bransford (Bransford, Sherwood, Hasselbring, Kinzer, & Williams, 1990), Reeves (Jih & Reeves, 1992), and Bereiter (Bowen, Bereiter, & Scardamalia, 1991). Their work includes a mixture of constructivist and cognitive approaches and methodologies, though they often speak in favor of an overall constructivist philosophy and approach for educational environments. Towards the more behaviorist corner of the triangle is Dick (1991) who ascribes to a much more directed approach to instruction and use of the Instructional Systems Design methodology. At the cognitive corner of the triangle are many educators and instructional designers including Rieber (1992), Reigeluth (1996), and Jacobson and Spiro (1995), who contend that the educational approach used should depend on goals, learners, and content, and that most educational environments must include a combination of behavioral, cognitive, and constructivist elements.

As stated earlier, the last category favors overall environments that have a cognitive flavor, but within it lessons and activities that cover the entire continuum of approaches. Some mathematical concepts, for example, may be learned best via constructivist laboratory activities whereas some math skills must be learned at a level of automaticity in a more directed fashion. In a complete educational environment, technology is but one component along with teachers, learners, books, and other media. Tools for exploring geometry or science are useful for constructivist laboratory activities. Drills are useful for practicing foreign languages or anatomy. Web-based hypermedia materials are useful for learners doing research. Integrating all of these, many multimedia packages defy categorization. Rather, they incorporate tutorial elements, drill elements, hyperlinks out to the Web, and simulation activities. Some interactions within a lesson are expository or directed and some are quite constructivist. This is as it should be. Educators should use a variety of multimedia materials and approaches, and thus provide flexible learning environments meeting the needs of the greatest number of their learners.

Implications for the Design of Educational Software

Design of educational software is a complex issue. It is easy to say that a variety of software methods are useful, are available, and that as an educator you should select and use a variety of them. It is somewhat more difficult to tell you to design and create software with a variety of approaches. Designing and developing *any* educational software is time consuming and difficult, so creating a variety of them is even more so. Some multimedia methodologies are more straightforward to develop (tutorial and drill) whereas others are more difficult (simulation and open-ended learning environments). What is appropriate for you depends on your experience, your subject area, your learners' needs and skills, and your educational philosophy. As a rule of thumb, the beginning multimedia designer should start with the simpler and more directed methodologies, such as tutorial and drill, before tackling more complex and constructivist methods, such as hypermedia, simulations, or open-ended learning environments.

Ultimately, we believe a successful teacher or a successful designer of instructional materials (including interactive multimedia) must adapt to the needs of different learners, subject areas, and situations. This is easiest if you adapt an eclectic approach to instruction, eschew labels such as objectivist or constructivist, and use a combination of all available methodologies and approaches. Accordingly, Chapters 4 through 11 of this book include some methodologies that are objectivist in nature (tutorials, drills, tests), some that are more constructivist in nature (tools, hypermedia, open-ended learning environments) and others that are both (games, simulations, and the Web).

Conclusion

The underlying basis of designing instructional multimedia is the theory of learning. There is considerable difference of opinion as to what conditions and actions most facilitate learning. A goal of this chapter has been to summarize the different approaches to learning theory and the concepts of each. Combining across the behavioral, cognitive, and constructivist approaches, these include principles of reinforcement, attention, perception, encoding, memory, comprehension, active learning, motivation, locus of control, mental models, metacognition, transfer of learning, individual differences, knowledge construction, situated learning, and collaborative learning. Designers of interactive multimedia should develop an understanding of all these and create materials based on them. That is not to say that design is simply a matter of applying these principles. Logistic considerations such as cost, dissemination, and ease of revision also influence design. The chapters to come will show how both are combined.

Lastly, this variety of educational approaches and learning theory concepts presents the designer with many difficult choices. For example, certain types of learner control may increase motivation but decrease achievement. A cooperative learning environment may provide benefits, such as increased interactivity, but also problems, such as less accommodation to individual differences. Instructional design is a series of compromises—a process of balancing multiple, worthwhile, but competing, goals, including achievement and motivation, time and money, learner and instructor satisfaction, initial learning and transfer of learning, and many more. Ultimately good learning environments begin with principles of learning and instruction, but require evaluation, revision, and fine tuning to balance these competing values and ensure that the benefits are accrued for all intended learners.

REFERENCES AND BIBLIOGRAPHY

Anderson, J. R. (1980). *Cognitive psychology and its implications.* San Francisco: W. H. Freeman.

Anderson, J. R. (1981). *Cognitive skills and their acquisition.* Hillsdale, NJ: Lawrence Erlbaum.

Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational Researcher, 25*(4), 5–11.

Anderson, R. C. (1977). The notion of schemata and the educational enterprise. In R. C. Anderson, R. J. Spiro, & W. E. Montague (Eds.), *Schooling and the acquisition of knowledge* (pp. 415–431). Hillsdale, NJ: Lawrence Erlbaum.

Ayllon, T., & Azrin, N. (1968). *The token economy: A motivational system for therapy and rehabilitation.* New York: Appleton-Century-Crofts.

Baker, F. B. (1978). *Computer-managed instruction: Theory and practice.* Englewood Cliffs, NJ: Educational Technology.

Bartlett, F. C. (1932). *Remembering.* London: Cambridge University Press.

Berger, D. E., Pezdek, K., & Banks, W. P. (1986). *Applications of cognitive psychology.* Hillsdale, NJ: Lawrence Erlbaum.

Block, J. H. (1980). Promising excellence through mastery learning. *Theory and Practice, 19,* 66–74.

Bowen, B., Bereiter, C., & Scardamalia, M. (1991). Computer-supported intentional learning environments. In F. V. Phillips (Ed.), *Thinkwork: Working, learning, and managing in a computer-interactive society* (pp. 87–98). New York: Praeger.

Bower, G. H., & Hilgard, E. R. (1981). *Theories of learning.* Englewood Cliffs, NJ: Prentice-Hall.

Bransford, J. D., Sherwood, R. D., Hasselbring, T. S., Kinzer, C. K., & Williams, S. M. (1990). Anchored instruction: Why we need it and how technology can help. In D. Nix & R. Spiro (Eds.), *Cognition, education and multimedia: Exploring ideas in high technology* (pp. 115–141). Hillsdale, NJ: Erlbaum.

Broad, M. L., & Newstrom, J. W. (1992). *Transfer of training: Action-packed strategies to ensure high payoff from training investments.* Reading, MA: Addison-Wesley.

Cameron, J., & Pierce, W. D. (1994). Reinforcement, reward, and intrinsic motivation: A meta-analysis. *Review of Educational Research, 64,* 363–423.

Cameron, J., & Pierce, W. D. (1996). The debate about rewards and intrinsic motivation: Protests and accusations do not alter the results. *Review of Educational Research, 66*(1), 39–51.

Cates, W. M. (1992, April). *Considerations in evaluating metacognition in interactive hypermedia/multimedia instruction.* Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco.

Chen, C., & Rada, R. (1996). Interacting with hypertext: A meta-analysis of experimental studies. *Human-Computer Interaction, 11*(2), 125–156.

Chou, C., & Lin, H. (1998). The effect of navigation map types and cognitive styles on learners' performance in a computer-networked hypertext learning system. *Journal of Educational Multimedia and Hypermedia, 7* (2/3), 151–176.

Clark, J. M., & Paivio, A. (1991). Dual coding theory and education. *Educational Psychology Review, 3,* 149–210.

Clark, R. E., & Voogel, A. (1985). Transfer of training principles for instructional design. *Educational Communication and Technology Journal, 33*(2), 113–123.

Cognition and Technology Group at Vanderbilt. (1992). An anchored instruction approach to cognitive skills acquisition and intelligent tutoring. In J. W. Regian & V. J. Shute (Eds.), *Cognitive approaches to automated instruction* (pp. 135–170). Hillsdale, NJ: Lawrence Erlbaum.

Cooper, P. A. (1993). Paradigm shifts in designed instruction: From behaviorism to cognitivism to constructivism. *Educational Technology, 33*(5), 12–19.

Cormier, S. M., & Hagman, J. D. (Eds.). (1987). *Transfer of learning: Contemporary research and applications.* San Diego: Academic Press.

De Corte, E., Linn, M. C., Mandl, H., & Verschaffel, L. (Eds.). (1991). *Computer-based learning environments for problem solving.* Berlin: Springer-Verlag.

Detterman, D. K., & Sternberg, R. J. (Eds.). (1993). *Transfer on trial: Intelligence, cognition, and instruction.* Norwood, NJ: Ablex.

Dick, W. (1991). An instructional designer's view of constructivism. *Educational Technology, 31*(5), 41–44.

Dickson, W. P. (1985). Thought-provoking software: Juxtaposing symbol systems. *Educational Researcher, 14*(5), 30–38.

Dillon, A., & Gabbard, R. (1998). Hypermedia as an educational technology: A review of the quantitative research literature on learner comprehension, control, and style. *Review of Educational Research, 68*(3), 322–349.

Duffy, T. M., & Cunningham, D. J. (1996). Constructivism: Implications for the design and delivery of instruction. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 170–198). New York: Simon & Schuster Macmillan.

Duffy, T. M., & Jonassen, D. H. (Eds.). (1992). *Constructivism and the technology of instruction: A conversation.* Hillsdale, NJ: Lawrence Erlbaum.

Duffy, T. M., Lowyck, J., & Jonassen, D. H. (Eds.). (1993). *Designing environments for constructivist learning.* Berlin: Springer-Verlag.

Fitzgerald, G. E., & Semrau, L. P. (1998). The effects of learner differences on usage patterns and learning outcomes with hypermedia case studies. *Journal of Educational Multimedia and Hypermedia, 7*(4), 309–331.

Fleming, M., & Levie, W. H. (1978). *Instructional message design: Principles from the behavioral sciences.* Englewood Cliffs, NJ: Educational Technology.

Fleming, M., & Levie, W. H. (1993). *Instructional message design: Principles from the behavioral and cognitive sciences* (2nd ed.). Englewood Cliffs, NJ: Educational Technology.

Flynn, J. L. (1992). Cooperative learning and Gagne's events of instruction: A syncretic view. *Educational Technology, 32*(10), 53–60.

Frederiksen, J. R., White, B. Y., & Gutwill, J. (1999). Dynamic mental models in learning science: The importance of constructing derivational linkages among models. *Journal of Research in Science Teaching, 36*(7), 806–836.

Gagné, E., Yekovich, C. W., & Yekovich, F. R. (1993). *The cognitive psychology of school learning* (2nd ed.). New York: HarperCollins.

Gagné, R. M. (1954). Training devices and simulators: Some research issues. *The American Psychologist, 9,* 95–107.

Gagné, R. M. (1985). *The conditions of learning and theory of instruction.* (4th ed.). New York: Holt, Rinehart and Winston.

Gagné, R. M., Foster, H., & Crowley, M. E. (1948). The measurement of transfer of training. *Psychological Bulletin, 45,* 97–130.

Gagné, R. M., & Medsker, K. L. (1996). *The conditions of learning: Training applications.* Fort Worth, TX: Harcourt Brace.

Garavaglia, P. L. (1996). The transfer of training: A comprehensive process model. *Educational Technology, 36*(2), 61–63.

Gavora, M. J., & Hannafin, M. (1995). Perspectives on the design of human–computer interactions: Issues and implications. *Instructional Science,* 22(6), 445–477.

Gentner, D., & Stevens, A. (Eds.). (1983). *Mental models.* Hillsdale, NJ: Lawrence Erlbaum.

Glaser, R. (1977). *Adaptive education: Individual diversity and learning.* New York: Holt.

Greeno, J. G., Smith, D. R., & Moore, J. L. (1993). Transfer of situated learning. In D. K. Detterman & R. J. Sternberg (Eds.), *Transfer on trial: Intelligence, cognition, and instruction* (pp. 99–167). Norwood, NJ: Ablex.

Hagmann, S., Mayer, R. E., & Nenninger, P. (1998). Using structural theory to make a word-processing manual more understandable. *Learning and Instruction, 8*(1), 19–35.

Hannafin, M. J. (1984). Guidelines for using locus of instructional control in the design of computer-assisted instruction. *Journal of Instructional Development, 7*(3), 6–10.

Hannafin, M. J., Hall, C., Land, S., & Hill, J. (1994). Learning in open-ended environments: Assumptions, methods, and implications. *Educational Technology, 34*(8), 48–55.

Hannafin, R. D., & Sullivan, H. J. (1995). Learner control in full and lean CAI programs. *Educational Technology Research and Development, 43*(1), 19–30.

Harel, I., & Papert, S. (Eds.). (1991). *Constructionism.* Norwood, NJ: Ablex.

Hicken, S., Sullivan, H., & Klein, J. (1992). Learner control modes and incentive variations in computer-assisted instruction. *Educational Technology Research and Development, 40*(4), 15–26.

Hooper, S., & Hannafin, M. J. (1991). The effects of group composition on achievement, interaction, and learning efficiency during computer-based cooperative instruction. *Educational Technology Research and Development, 39*(3), 27–40.

Hooper, S., Temiyakarn, C., & Williams, M. D. (1993). The effects of cooperative learning and learner control on high- and average-ability students. *Educational Technology Research and Development, 41*(2), 5–18.

Jacobson, M. J., & Spiro, R. J. (1995). Hypertext learning environments, cognitive flexibility, and the transfer of complex knowledge: An empirical investigation. *Journal of Educational Computing Research, 12*(4), 301–333.

Jih, H. J., & Reeves, T. C. (1992). Mental models: A research focus for interactive learning systems. *Educational Technology Research and Development, 40*(3), 39–53.

Johnson, D. W., & Johnson, R. T. (1985, October). Cooperative learning: One key to computer assisted learning. *The Computing Teacher, 13*(2), 11–15.

Johnson, D. W., & Johnson, R. T. (1996). Cooperation and the use of technology. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 1017–1044). New York: Simon & Schuster Macmillan.

Johnson, R. T., Johnson, D. W., & Stanne, M. B. (1985). Effects of cooperative, competitive, and individualistic goal structures on computer-assisted instruction. *Journal of Educational Psychology, 77,* 668–677.

Johnson, R. T., Johnson, D. W., & Stanne, M. B. (1986). Comparison of computer-assisted cooperative, competitive, and individualistic learning. *American Educational Research Journal, 23*(3), 382–392.

Jonassen, D. H. (1988). Integrating learning strategies into courseware to facilitate deeper processing. In D. H. Jonassen (Ed.), *Instructional designs for microcomputer courseware* (pp. 151–181). Hillsdale, NJ: Lawrence Erlbaum.

Jonassen, D. H. (1991). Objectivism versus constructivism: Do we need a new philosophical paradigm? *Educational Technology Research and Development, 39*(3), 5–14.

Jonassen, D. H. (Ed.). (1996). *Handbook of research for educational communications and technology.* New York: Simon & Schuster Macmillan.

Jonassen, D. H. (2000). *Computers as mindtools for schools: Engaging critical thinking.* Upper Saddle River, NJ: Merrill.

Jonassen, D. H., & Henning, P. (1999). Mental models: Knowledge in the head and knowledge in the world. *Educational Technology, 39*(3), 37–42.

Jonassen, D. H., Hennon, R. J., Ondrusek, A., Samouilova, M., Spaulding, K. L., Yueh, H.-P., Li, T., Nouri, V., DiRocco, M., & Birdwell, D. (1997). Certainty, determinism, and predictability in theories of instructional design: Lessons from science. *Educational Technology, 37*(1), 27–34.

Jones, M., & Winne, P. H. (Eds.). (1992). *Adaptive learning environments: Foundations and frontiers.* Berlin: Springer-Verlag.

Kafai, Y. B. (1995). *Minds in play: Computer game design as a context for children's learning.* Hillsdale, NJ: Lawrence Erlbaum.

Kang, S.-H. (1996). The effects of using an advance organizer on students' learning in a computer simulation environment. *Journal of Educational Technology Systems, 25*(1), 57–65.

Kearsley, G., & Shneiderman, B. (1998). Engagement theory: A framework for technology-based teaching and learning. *Educational Technology, 38*(5), 20–23.

Keller, J. M., & Suzuki, K. (1988). Use of the ARCS motivation model in courseware design. In D. H. Jonassen (Ed.), *Instructional designs for microcomputer courseware* (pp. 401–434). Hillsdale, NJ: Lawrence Erlbaum.

Klein, J. D., & Pridemore, D. R. (1992). Effects of cooperative learning and need for affiliation on performance, time on task, and satisfaction. *Educational Technology Research and Development, 40*(4), 39–47.

Kohn, A. (1996). By all available means: Cameron and Pierce's defense of extrinsic motivators. *Review of Educational Research, 66*(1), 1–4.

Kolb, D. (1985). *The learning style inventory* (2nd ed.). Boston: McBer.

Kozma, R. B. (1987). The implication of cognitive psychology for computer-based learning tools. *Educational Technology, 27*(11), 20–25.

Laurillard, D. (1987). Computers and the emancipation of students: Giving control to the learner. *Instructional Science, 16,* 3–18.

Lawless, K. A., & Brown, S. W. (1997). Multimedia learning environments: Issues of learner control and navigation. *Instructional Science, 25*(2), 117–131.

Leader, L. F., & Klein, J. D. (1996). The effects of search tool type and cognitive style on performance during hypermedia databases searches. *Educational Technology Research and Development, 44*(2), 5–15.

Lebow, D. (1993). Constructivist values for instructional systems design: Five principles toward a new mindset. *Educational Technology Research and Development, 41*(3), 4–16.

Lepper, M. R., & Chabay, R. W. (1985). Intrinsic motivation and instruction: Conflicting views on the role of motivational processes in computer-based education. *Educational Psychologist, 20*(4), 217–230.

Lepper, M. R., Keavney, M., & Drake, M. (1996). Intrinsic motivation and extrinsic rewards: A commentary on Cameron and Pierce's meta-analysis. *Review of Educational Research, 66*(1), 5–32.

Lieberman, D. A., & Linn, M. C. (1991). Learning to learn revisited: Computers and the development of self-directed learning skills. *Journal of Research on Computing in Education, 23*(3), 373–395.

Lin, X., & Lehman, J. D. (1999). Supporting learning of variable control in a computer-based biology environment: Effects of prompting college students to reflect on their own thinking. *Journal of Research in Science Teaching, 36*(7), 837–858.

Liu, M., & Reed, W. M. (1994). The relationship between the learning strategies and learning styles in a hypermedia environment. *Computers in Human Behavior, 10*(4), 419–434.

Lundberg, I., & Olofsson, A. (1993). Can computer speech support reading comprehension? *Computers in Human Behavior, 9*(2/3), 283–293.

MacLachlan, J. (1986). Psychologically based techniques for improving learning within computerized tutorials. *Journal of Computer-Based Instruction, 13*(3), 65–70.

Malone, T. W. (1981). Towards a theory of intrinsically motivating instruction. *Cognitive Science, 5,* 333–369.

Malone, T. W., & Lepper, M. R. (1987). Making learning fun: A taxonomy of intrinsic motivations for learning. In R. E. Snow & M. J. Farr (Eds.), *Aptitude, learning, and instruction: III. Conative and affective process analysis* (pp. 223–253). Hillsdale, NJ: Lawrence Erlbaum.

Mayer, R. E. (1992). *Thinking, problem solving, cognition.* (2nd ed.). New York: W. H. Freeman and Company.

Mayer, R. E. (1997). Multimedia learning: Are we asking the right questions? *Educational Psychologist, 32*(1), 1–19.

Mayer, R. E. (1998). Cognitive, metacognitive, and motivational aspects of problem solving. *Instructional Science, 26*(1–2), 49–63.

Mayer, R. E. (1999). *The promise of educational psychology: Learning in the content areas.* Upper Saddle River, NJ: Merrill/Prentice Hall.

Mayer, R. E., Steinhoff, K., Bower, G., & Mars, R. (1995). A generative theory of textbook design: Using annotated illustrations to foster meaningful learning of science text. *Educational Technology Research and Development, 43*(1), 31–43.

McInerney, V., McInerney, D. M., & Marsh, H. W. (1997). Effects of metacognitive strategy training within a cooperative group learning context on computer achievement and anxiety: An aptitude-treatment interaction study. *Journal of Educational Psychology, 89*(4), 686–695.

Merrill, M. D. (1991). Constructivism and instructional design. *Educational Technology, 31*(5), 45–53.

Messick, S. (1994). The matter of style: Manifestations of personality in cognition, learning and teaching. *Educational Psychologist,* 29, 121–136.

Mevarech, Z. R. (1993). Who benefits from cooperative computer-assisted instruction? *Journal of Educational Computing Research, 9*(4), 451–464.

Mevarech, Z. R., Silber, O., & Fine, D. (1991). Learning with computers in small groups: Cognitive and affective outcomes. *Journal of Educational Computing Research, 7*(2), 233–243.

Milheim, W. D., & Martin, B. L. (1991). Theoretical bases for the use of learner control: Three different perspectives. *Journal of Computer-Based Instruction, 18*(3), 99–105.

Mitchell, P. D. (1994). Learning style: A critical analysis of the concept and its assessment. In R. Hoey (Ed.), *Designing for learning: Effectiveness with efficiency* (pp. 5–10). London: Kogan Page.

Moore, J. L., Lin, X., Schwartz, D. L., Petrosino, A., Hickey, D. T., Campbell, O., Hmelo, C., & The Cognition and Technology Group at Vanderbilt. (1994). The relationship between situated cognition and anchored instruction: A response to Tripp. *Educational Technology, 34*(8), 28–32.

Nelson, C. S., Watson, J. A., Ching, J. K., & Barrow, P. I. (1997). The effect of teacher scaffolding and student comprehension monitoring on a multimedia/interactive videodisc science lesson for second graders. *Journal of Educational Multimedia and Hypermedia, 5*(3/4), 317–348.

Newby, T. J., Ertmer, P. A., & Stepich, D. A. (1995). Instructional analogies and the learning of concepts. *Educational Technology Research and Development, 43*(1), 5–18.

O'Neil, H. F. (Ed.). (1979a). *Issues in instructional systems development.* New York: Academic Press.

O'Neil, H. F. (Ed.). (1979b). *Procedures for instructional systems development.* New York: Academic Press.

Orey, M. A., & Nelson, W. A. (1997). The impact of situated cognition: Instructional design paradigms in transition. In C. R. Dills & A. J. Romiszowski (Eds.), *Instructional development paradigms* (pp. 283–296). Englewood Cliffs, NJ: Educational Technology.

Osman, M. E., & Hannafin, M. J. (1992). Metacognition research and theory: Analysis and implications for instructional design. *Educational Technology Research and Development, 40*(2), 83–99.

Papert, S. (1980). *Mindstorms: Children, computers and powerful ideas.* New York: Basic Books.

Park, I., & Hannafin, M. J. (1993). Empirically based guidelines for the design of interactive multimedia. *Educational Technology Research and Development, 41*(3), 63–85.

Park, O.-C. (1998). Visual displays and contextual presentation in computer-based instruction. *Educational Technology Research and Development, 46*(3), 37–50.

Park, O.-C., & Gittelman, S. S. (1992). Selective use of animation and feedback in computer-based instruction. *Educational Technology Research and Developmert, 40*(4), 27–38.

Park, O.-C., & Gittelman, S. S. (1995). Dynamic characteristics of mental models and dynamic visual displays. *Instructional Science, 23*(5–6), 303–320.

Pavlov, I. P. (1927). *Conditioned reflexes*. London: Clarendon Press.

Qin, Z., Johnson, D. W., & Johnson, R. T. (1995). Cooperative versus competitive efforts and problem solving. *Review of Educational Research, 65*(2), 129–143.

Reigeluth, C. M. (1996). A new paradigm of ISD? *Educational Technology, 36*(3), 13–20.

Reigeluth, C. M. (Ed.). (1999). *Instructional-design theories and models: A new paradigm of instructional theory* (Vol. 2). Mahwah, NJ: Lawrence Erlbaum.

Relan, A. (1995). Promoting better choices: Effects of strategy training on achievement and choice behavior in learner-controlled CBI. *Journal of Educational Computing Research, 13*(2), 129–149.

Renkl, A., Mandl, H., & Gruber, H. (1996). Inert knowledge: Analyses and remedies. *Educational Psychologist, 31*(2), 115–121.

Resnick, M. (1994). *Turtles, termites, and traffic jams: Explorations in massively parallel microworlds*. Cambridge, MA: MIT Press.

Rieber, L. P. (1992). Computer-based microworlds: A bridge between constructivism and direct instruction. *Educational Technology Research and Development, 40*(1), 93–106.

Rieber, L. P. (1994). *Computers, graphics, & learning*. Madison, WI: W.C.B. Brown & Benchmark.

Rieber, L. P. (1996). Animation as feedback in a computer-based simulation: Representation matters. *Educational Technology Research and Development, 44*(1), 5–22.

Rieber, L. P., & Parmley, M. W. (1995). To teach or not to teach? Comparing the use of computer-based simulation in deductive versus inductive approaches to learning with adults in science. *Journal of Educational Computing Research, 13*(4), 359–374.

Ritchie, D., & Gimenez, F. (1995). Effectiveness of graphic organizers in computer-based instruction with dominant Spanish-speaking and dominant English-speaking students. *Journal of Research on Computing in Education, 28*(2), 221–233.

Rojas-Drummond, S., Hernández, G., Vélez, M., & Villagrán, G. (1998). Cooperative learning and the appropriation of procedural knowledge by primary school children. *Learning and Instruction, 8*(1), 37–61.

Romiszowski, A. J., & Ravitz, J. (1997). Computer-mediated communication. In C. R. Dills & A. J. Romiszowski (Eds.), *Instructional development paradigms* (pp. 745–768). Englewood Cliffs, NJ: Educational Technology.

Ryan, R. M., & Deci, E. L. (1996). When paradigms clash: Comments on Cameron and Pierce's claim that rewards do not undermine intrinsic motivation. *Review of Educational Research, 66*(1), 33–38.

Rysavy, S. D. M., & Sales, G. C. (1991). Cooperative learning in computer-based instruction. *Educational Technology Research and Development, 39*(2), 70–79.

Savery, J. R., & Duffy, T. M. (1995). Problem based learning: An instructional model and its constructivist framework. *Educational Technology, 35*(5), 31–38.

Schank, R., & Cleary, C. (1995). *Engines for education*. Hillsdale, NJ: Lawrence Erlbaum.

Schauble, L., Raghavan, K., & Glaser, R. (1993). The discovery and reflection notation: A graphical trace for supporting self-regulation in computer-based laboratories. In S. P. Lajoie & S. J. Derry (Eds.), *Computers as cognitive tools* (pp. 319–337). Hillsdale, NJ: Lawrence Erlbaum.

Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional Science, 26*(1–2), 113–125.

Seel, N. M. (1992, April). *Mental models and the transfer of learning*. Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco.

Shin, M. (1998). Promoting students' self-regulation ability: Guidelines for instructional design. *Educational Technology, 38*(1), 38–44.

Shore, A., & Johnson, M. F. (1992). Integrated learning systems: A vision for the future. *Educational Technology, 32*(9), 36–39.

Simons, P. R.-J. (1993). Constructive learning: The role of the learner. In T. M. Duffy, J. Lowyck, & D. H. Jonassen (Eds.), *Designing environments for constructivist learning* (pp. 291–319). Berlin: Springer-Verlag.

Skinner, B. F. (1938). *The behavior of organisms.* New York: Appleton-Century-Crofts.

Skinner, B. F. (1948). *Walden Two.* New York: Macmillan.

Skinner, B. F. (1968). *The technology of teaching.* New York: Appleton-Century Crofts.

Skinner, B. F. (1969). *Contingencies of reinforcement: A theoretical analysis.* New York: Appleton-Century-Crofts.

Skinner, B. F. (1974). *About behaviorism.* New York: Knoph.

Slavin, R. E. (1990). *Cooperative learning.* Englewood Cliffs, NJ: Prentice Hall.

Steinberg, E. R. (1989). Cognition and learner control: A literature review, 1977–1988. *Journal of Computer-Based Instruction, 16*(4), 117–121.

Stephenson, S. D. (1994). The use of small groups in computer-based training: A review of recent literature. *Computers in Human Behavior, 10*(3), 243–259.

Sternberg, R. J. (1998). Metacognition, abilities, and developing expertise: What makes an expert student? *Instructional Science, 26*(1-2), 127–140.

Sternberg, R. J., & Frensch, P. A. (1993). Mechanisms of transfer. In D. K. Detterman & R. J. Sternberg (Eds.), *Transfer on trial: Intelligence, cognition, and instruction* (pp. 25–38). Norwood, NJ: Ablex.

Strike, K. A. (1975). The logic of learning by discovery. *Review of Educational Research, 45*(3), 461–483.

Susman, E. B. (1998). Cooperative learning: A review of factors that increase the effectiveness of cooperative computer-based instruction. *Journal of Educational Computing Research, 18*(4), 303–322.

Thorndike, E. L. (1913). *Educational psychology: The psychology of learning* (Vol. 2). New York: Teachers College Press.

Veenman, M. V. J., Elshout, J. J., & Meijer, J. (1997). The generality vs domain-specificity of metacognitive skills in novice learning across domains. *Learning and Instruction, 7*(2), 187–209.

Weinstein, C. E., Goetz, E. T., & Alexander, P. A. (Eds.). (1988). *Learning and study strategies: Issues in assessment, instruction, and evaluation.* San Diego: Academic Press.

White, B. Y. (1993). Intermediate causal models: A missing link for successful science education. In R. Glaser (Ed.), *Advances in instructional psychology* (Vol. 4, pp. 177–252). Hillsdale, NJ: Lawrence Erlbaum.

White, B. Y., & Frederiksen, J. R. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction, 16*(1), 3–118.

White, B. Y., & Horowitz, P. (1987). *ThinkerTools: Enabling children to understand physical laws.* (Report No. 6470). Cambridge, MA: BBN Laboratories.

Wilson, B. G. (1997). Reflections on constructivism and instructional design. In C. R. Dills & A. J. Romiszowski (Eds.), *Instructional development paradigms* (pp. 63–80). Englewood Cliffs, NJ: Educational Technology.

Winn, W., & Snyder, D. (1996). Cognitive perspectives in psychology. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 112–142). New York: Simon & Schuster Macmillan.

Wittrock, M. C. (1974). Learning as a generative process. *Educational Psychologist, 11*(2), 87–95.

Wizer, D. R. (1995). Small group instruction using microcomputers: Focus on group behaviors. *Journal of Research on Computing in Education, 28*(1), 121–132.

Yelon, S. L. (1996). *Powerful principles of instruction.* White Plains, NY: Longman.

Young, J. D. (1996). The effect of self-regulated learning strategies on performance in learner controlled computer-based instruction. *Educational Technology Research and Development, 44*(2), 17–27.

Yu, F.-Y. (1996). Competition or noncompetition: Its impact on interpersonal relationships in a computer-assisted learning environment. *Journal of Educational Technology Systems, 25*(1), 13–24.

Yueh, J.-S., & Alessi, S. M. (1988). The effect of reward structure and group ability composition on cooperative computer assisted learning. *Journal of Computer-Based Instruction, 15*(1), 18–22.

CHAPTER 3

General Features of Software for Learning

Chapters 4 through 11 discuss each of the main methodologies for interactive multimedia: tutorials, hypermedia, drills, simulations, games, tools and open-ended learning environments, tests, and Web-based learning. Each chapter focuses on the *factors* pertinent to that methodology. *Factors* are those characteristics under the designer's control that affect the appearance, function, and effectiveness of the software.

There are also instructional factors relevant to and common to *all* interactive multimedia. Those factors can be organized into the following categories:

- *Introduction* of the program
- *Learner control*
- *Presentation* of information
- Providing *help*
- *Ending* a program

Introduction of a Program

Three factors are relevant to the introduction of any program:

- Title page
- Directions
- User identification

Title Page

Practically all multimedia programs begin with a title page (Figure 3.1). Even general purpose applications like word processors display what is commonly known as a *splash screen* to identify the program. A title page may serve several purposes:

FIGURE 3.1
A Title Page

- To tell you what program you are about to use
- To tell you in a general way what the program is about
- To attract your attention and create a receptive attitude
- To inform you of the author's or publisher's name and contact information
- To provide copyright information
- To provide an escape if you realize you have come to the wrong place

Title pages vary from simple, with a program and author name, to elaborate pages with text, movies, and music. Some authors (e.g., Gagné, Wager, & Rojas, 1981) suggest that a title page should include elements to motivate the user. Although we do not disagree, motivational devices should be balanced against the importance of keeping a title page short, clear, and to the point. Our recommendations for title (or splash) pages are as follows:

- Always provide a title page or splash screen.
- Make the page clever and interesting but short.
- If you include movies, speech, music, or animation, allow users to skip them by clicking the mouse or keyboard. A program may be used many times by instructors and some learners. Long and unavoidable sequences are annoying for repeat users.
- A title page should *not* disappear after a fixed number of seconds. The *user* should decide when to continue by mouse or keyboard.
- Make it absolutely clear how to continue the program.
- Always include a title, author or owner name, copyright date, and a button to exit.
- Provide credits if they are short; longer credits should be on a separate page.
- Do not put menus, directions, or content to be learned on a title page.

Directions

Directions (Figure 3.2) are essential in any multimedia program. However, that does not mean that *every* user needs them. As with title pages, first-time users have different needs and expectations than repeat users of a program. The design of directions pages can be quite complex, taking into consideration what to include, when to provide them, who is viewing them, and how much detail to give. Following are our recommendations for directions.

Do *not* include basic directions for computer operation unless you know your users are computer novices. Many multimedia programs begin with directions for clicking the mouse or pressing the RETURN key. Increasingly, users know this type of information and neither their time nor a programmer's time should be spent on them.

Include information that is specific to the program, such as how to use its particular pull-down menus or buttons. Do *not* include directions at the beginning of a program for procedures that are used only much later in the program. For example, suppose the user is given a practice test or quiz at the end of the program, which may not occur for thirty minutes or more. Give the directions for the test *when the test occurs* and not in directions at the beginning when they risk being forgotten.

Keep directions simple and self-evident. Users should not need directions on how to operate the directions page. Our general recommendation for this and other factors (such as the amount of detail in text) is to start with *minimal* content and determine through user testing if more detail is needed. Keep the level of detail appropriate. For example, more careful explanation tends to be needed for keyboard-based actions than for mouse-based actions. If activities are complicated (as in simulations) or important (as in achievement tests), consider providing both demonstration and practice of the activity.

If directions include movies, audio, or animation, they should be short and include options (usually buttons) to *pause*, to *continue*, to *repeat*, and to *skip* that information.

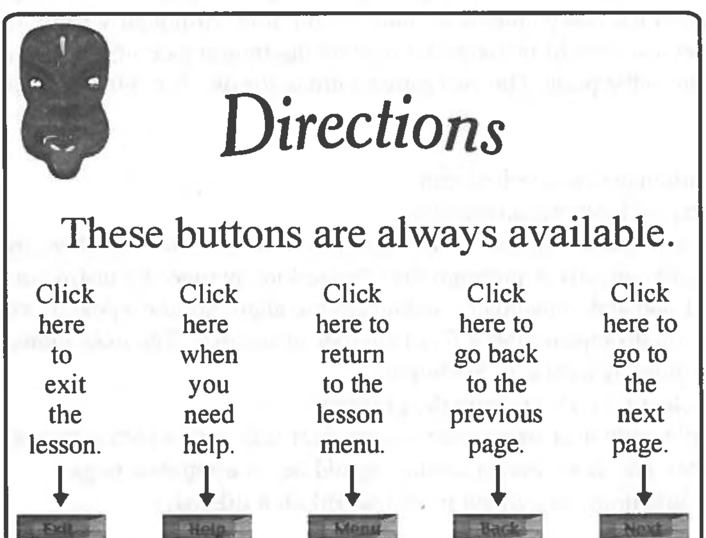

FIGURE 3.2
A Directions Page

It should be easy to skip or exit the directions and obvious how to do so. This is especially important for repeat users of a program. The user should be able to return to directions easily and quickly from anywhere in the program. This is especially true for complex directions like the rules of a game or operation of equipment in a simulation.

Keep the length of initial directions short by including context-sensitive help throughout the program, a topic we will return to later. Context-sensitive help provides assistance to the user for that part of the program only for which help is requested. The use of rollovers is both useful *in* directions and *throughout* a program to help keep the directions short (Lee, 1996). A rollover is information that appears when the user simply points at something (without clicking) with the mouse. For example, a button may simply contain an arrow pointing to the right, but when the user points at that button, text appears nearby saying, for example, "Go to next page."

Last, directions should emphasize operation of the program, such as navigation. Do not put instructional objectives, credits, or subject-matter content in the directions.

User Identification

Many programs ask the user for a name or other form of identification. This may be done to store or retrieve data, to ascertain that the user is authorized to use the program, or to address the user by name throughout the program. Recommendations for identification pages follow:

- Only include an identification page if you are going to use the identification.
- Keep the amount of typing to a minimum.
- Make the entry procedure self-evident and avoid lengthy directions.
- Allow the user to correct their identification in the event of typographical errors.
- If secret identification information (e.g., a password) is entered, it should not appear on the screen.
- If you wish to encourage collaborative learning, allow for multiple names or IDs to be entered.

Learner Control of a Program

The term *locus of control* refers to whether control of a program is given to the user or resides in the program. Of course, both user and program control always exist in some combination. Operationally, the designer and programmer provide options for learner control, and whatever they do not provide for the learner is controlled by the program. Three considerations concern the design of learner controls: *what and how much* the learner can control, the *method* of control, and the *mode* of control.

What and How Much Control to Provide

Research on learner control in computer-based instruction is extensive. It has long been suggested, even before the existence of microcomputers, that learners may be able to make better sequencing decisions about their own learning activities than can teachers (Bruner, 1966).

Based on this, an early CBI system called *TICCIT* (Merrill, Schneider, & Fletcher, 1980) provided almost complete learner control of program sequence and other parameters. This system was designed primarily for adult education. The learner using TICCIT (*T*ime-shared, *I*nteractive, *C*omputer-*C*ontrolled, *I*nformation *T*elevision) decided at any time which part of a curriculum to study; whether to view rules, examples, or practice problems; the difficulty level of practice problems; and when to take a test. These and other decisions were easily made using a special keyset having keys labeled *rule, example, practice, easy, hard,* and *help.*

In contrast to the TICCIT approach, many studies investigating learner control have suggested that learners do not always make good decisions and that the more control given to the learner, the more learning may suffer (Ayersman, 1995; Steinberg, 1989). It has been suggested that learner control is more beneficial when learners receive specific feedback regarding their progress and the success of their decisions (Tennyson, 1981) or when they receive explicit instruction on proper control of programs. It has also been suggested that learners with greater ability or more prior knowledge of the subject matter make better use of learner control options (Chung & Reigeluth, 1992; Shin, Schallert, & Savenye, 1994).

In recent years, especially with the constructivist emphasis on providing greater learner control, the controversy about it has increased (e.g., Hannafin & Sullivan, 1995; Lawless & Brown, 1997; Relan, 1995; Williams, 1996). Reeves (1993) suggested that many of the studies investigating locus of control were poorly done (which he termed *pseudoscience*) and that high degrees of user control should be given greater consideration by today's designers.

Although further research can provide more advice about design of learner control, the best approach right now is to provide intelligently *some* learner control for appropriate aspects of a program depending on the methodology, the educational level of the learner, the program complexity, and the overall educational philosophy (Psotka, Kerst, Westerman, & Davison, 1994). Design of learner control depends very much on the methodology of a program. As a result, Chapter 4 provides specific recommendations for learner control of tutorials, Chapter 5 for hypermedia, and so on. Here we make only general recommendations based on research to date and our own experience.

- The most important learner controls concern sequence (which includes moving forward, moving backward, and selecting what to do next) and pace (how fast processes occur). More optional controls are for content difficulty and learning strategy (which tend to vary for different methodologies).
- Always permit learner control of forward progression.
- Do *not* use timed pauses. A timed pause is progression to the next step after a fixed number of seconds, rather than when the user clicks or presses a key.
- Allow the learner to review, such as with backward paging, whenever possible.
- Always allow the learner *temporary termination* of a program. This means being able to temporarily end the program and return to it later, preferably with some mechanism to continue in the program where one left off (called *bookmarking*).
- For general capabilities, such as directions, help, complaints, glossaries, and temporary termination, provide the learner with consistent *global* control available everywhere in the program.

- Whenever there are movies, audio, or animations, allow the learner to pause, continue, repeat, or skip them. If the movie or other information is long (more than ten or twenty seconds), also provide fast-forward and rewind controls.
- Give adults more control than children.
- Give learners with more content experience (prior knowledge of the content) greater control than those with little content experience.
- Know your users and provide controls appropriate for their needs. For example, if your users have widely varying reading skills, provide a choice of either text or speech. If your users are not all likely to have English as their native language, provide a choice of language for text and speech.
- Base learner controls on content. You should generally provide more *learner* control for problem-solving and higher-order thinking skills and more *program* control for procedural learning and simpler skills.
- If mastery of content is critical (such as when the consequences of errors are dangerous), use more program control.
- If performance is poor, restrict learner controls or give the learner advice about better use of the controls.

Methods of Control

For those factors the learner *may* control, the methods used can determine the ease of use and consequently the extent to which learners take advantage of them. Modern multimedia can include a bewildering assortment of methods and modes for control, including buttons, full-screen menus, pull-down menus, pop-up menus, typed commands, keypress commands, hot words, hot icons and pictures, scroll bars, tabs, tear-off menus, pallets, and toolbars. These may be combined as well, such as pallets with tabs to access layers of the pallet.

Once again it is important to know your users—a topic discussed in more detail in Chapter 13. They may be learners who use your program only once, as is often the case with instructional programs, or they may return to finish or review the program. They may be instructors who frequently demonstrate the program to learners. Each user has different needs. In general, a large assortment of controls is appropriate in programs intended for professionals or for those who use them repeatedly. Programs for one-time users should strive for simplicity. In keeping with that goal, consider the three most common and appropriate methods of control: buttons, menus, and hyperlinks.

Buttons Screen buttons are among the most popular and most "user-friendly" methods of control. Buttons may be labeled with words or pictures (icons) to signify their purpose and action. Buttons are best for a limited number of *local controls,* those controls relevant to the current display and its contents. Buttons are thus common for actions such as going to the next or previous page, playing a sound or movie, or selecting an option on a multiple-choice question. Buttons have the advantage of being visible and thus reminding learners of things that can be done. Buttons have the disadvantage of taking up screen space and distracting from other screen elements.

We recommend using buttons for a small number of local controls. Avoid a large number of buttons on the screen. When there are a large number of controls available, especially *global* controls (controls available everywhere in a program), it may be better to put them in menus, discussed shortly.

The function of buttons should be clear. Each should contain an unambiguous picture or text label indicating its purpose. We also recommend using cursor change and rollovers, by which pointing at a button causes the cursor to change shape (such as from an arrow to a little pointing hand) and additional clarifying information to appear nearby (such as a text box with a brief description of the purpose of the button).

Finally, we recommend that buttons provide *confirmation*. This is most easily done if a button is activated by the mouse. Clicking the mouse when the cursor is over the screen button should highlight it, confirming precisely which screen button the user has selected. Releasing the mouse button completes the selection. Confirmation is typically done by making the button brighter, a different color, or appear to be "depressed" (a three-dimensional effect). Buttons with clear meanings, rollovers, and confirmation provide a friendly user interface.

Menus Menus are lists of options that can be displayed on the screen in a variety of ways. Sometimes they are lists with buttons; sometimes without. Sometimes they are on the screen the whole time as is often the case on the World Wide Web. Other times they are hidden, or partly hidden, so as not to take up too much screen space. Three general types of menus can be used: full-screen menus, hidden menus, and frame menus.

Full-screen menus fill the entire screen (or a large part of it) with a list of user control options, as illustrated in Figure 3.3. In several multimedia methodologies, full-screen menus are used for learners to select and go to various parts of a program. Full-screen menus have some clear advantages. They can explain each choice with detailed text. They can provide a good place to begin a section of a program or go to at the end of a section, thus serving as an anchor point that gives learners a sense of orientation or being in a familiar place. They can also provide progress information (by indicating sections completed or the current section in progress) and achievement information (such as the

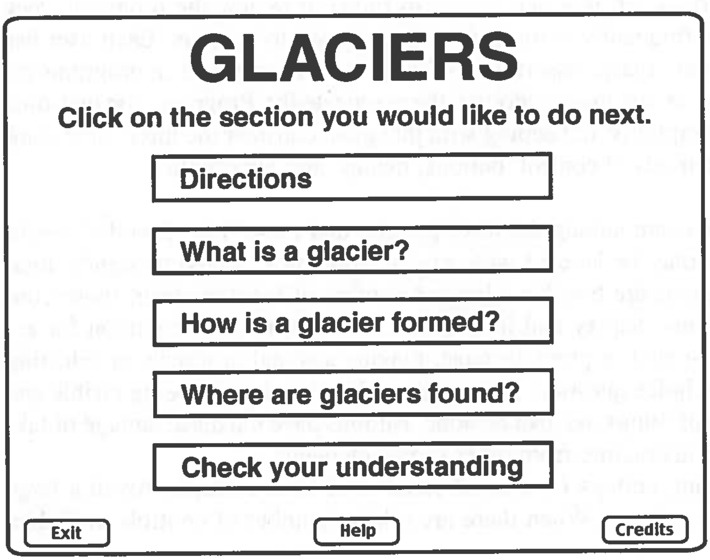

FIGURE 3.3
A Full-Screen Menu

percentage of questions answered correctly in each section). They have the disadvantages of taking up display space (covering or replacing other information), requiring the learner to "leave" the page they are on to display the menu, and not always being readily available. Finally, providing more than one full-screen menu can be disorienting. They work best when a program needs only one main full-screen menu.

Hidden menus include pull-down menus (Figure 3.4), pop-up menus, tear-off menus, and several other types. The most common is the pull-down menu popularized in the Windows and Macintosh operating systems. Menu categories such as *GoTo* or *Help* appear in a row along the top (and sometimes the bottom) of the screen or a window. When a category is chosen, a list of options appears below the category (such as a *GoTo* menu displaying *Definitions, Rules,* and *Directions* below it). The user then selects the option desired. A screen button can also be used to display a list of options.

Pull-down menus have several advantages. They are built into most modern operating systems and authoring programs and are thus easy to implement. Many user choices may be available that take up only a small amount of screen space (the bar containing the main menu categories). They may be *hierarchical,* with categories expanding to choices that in turn expand into subchoices several levels deep. They do not require leaving the current screen you are viewing, as they simply overlay the current information, which helps preserve user orientation. Schuerman and Peck (1991) suggest that pull-down menus provide a good type of sequence control for programs with a two-dimensional content structure (several sections with subsections in each). They allow the learner not only quick access to any section, but also a view of the complete program layout at any time without leaving the current page or activity. Figure 3.4 illustrates pull-down menus that reflect the structure of a program about birds of the world, with countries organized into continents.

Pull-down menus also have disadvantages. They are a little more difficult to operate than other methods, requiring mouse "dragging" or multiple clicks or keypresses. They are typically unattractive, often allowing only black and white text. They are usually limited

FIGURE 3.4

Pull-Down Menus Showing a Lesson's Structure

to a single text font, making foreign language menus difficult. They are often relegated to the top of the screen, whereas many designers prefer to place user controls at the bottom of the screen and to use the top for orienting information, such as page or section labels. Some of these problems may be circumvented by *imitating* the operating system's pull-down menus (although that requires more sophisticated programming) or by using button-generated pop-up menus. The final disadvantage of pull-down menus is that learners ignore or forget to use them. We have often observed that learners do not access glossaries or help options that are available through a pull-down menu, but do access them when available via a button.

Pull-down menus (and other hidden menus) are good for global controls—those available all the time, such as going to a glossary or exiting a program. Pull-down menus are *not* particularly good for local controls—those which change from screen to screen—because the user does not know they are changing or must be constantly reminded of the options, which is cumbersome. Pull-down menus are also not good for frequent actions, such as going to the next page, because they require multiple clicks, dragging, or keypresses.

Frame menus (Figure 3.5) are an increasingly common feature of programs on the World Wide Web and are beginning to appear in other programs as well. A frame menu is a split-screen method. Typically, the left third (or less) of the screen is devoted to a list of menu options that are displayed all the time. The menu may include text, icons, pictures, or anything else (unlike pull-down menus). The remainder of the screen (typically the right two-thirds or more) is devoted to the content of the program. The advantage of frame menus is that learners always see the options and structure, thus providing a good sense of orientation. They are easy to use and learners always have a visual reminder of their availability. They can contain any of the features of full-screen menus, such as text in any language, pictures, progress information, or section scores. The main disadvan-

FIGURE 3.5
A Frame Menu

tage is that they reduce the amount of screen space available for the main program (content and activities) and can create a cluttered appearance. Being a new technique, support for frame menus is not built into all operating systems or authoring programs. When they are used (primarily on the Web), they are prone to bugs.

Some recommendations and ideas for the use of menus in interactive multimedia programs follow:

- Provide menus for program sequence control if section sequence is *not* critical.
- Provide menus more for adults than for children.
- Make menus always be accessible.
- Use a *progressive* menu (Figure 3.6) to provide *reviewing* but not *skipping*.
- Give full-screen menus a good header name, not *Menu* (Figure 3.3).
- Give advice and progress information on a menu depicting the sections of a program (Figure 3.6).
- Keep the choices in a menu simple and few in number (Shneiderman, 1998).
- For hierarchical menus, keep the *levels* few in number (Shneiderman, 1998).
- For programs with complex structure, either do not provide initial choice or provide a few simple choices. Complex program structures also may be more readily depicted with pictures, such as a map, block diagram, or flowchart.
- Use menus for global controls, such as choosing the next activity, obtaining help, or exiting the program.
- Include options to return to directions and to exit the program.
- Do *not* use menus for very frequent actions like going to the next page.
- Use full-screen or frame menus for programs with simple structure.
- Use pull-down or pop-up menus for programs with hierarchical or other more complex structure.

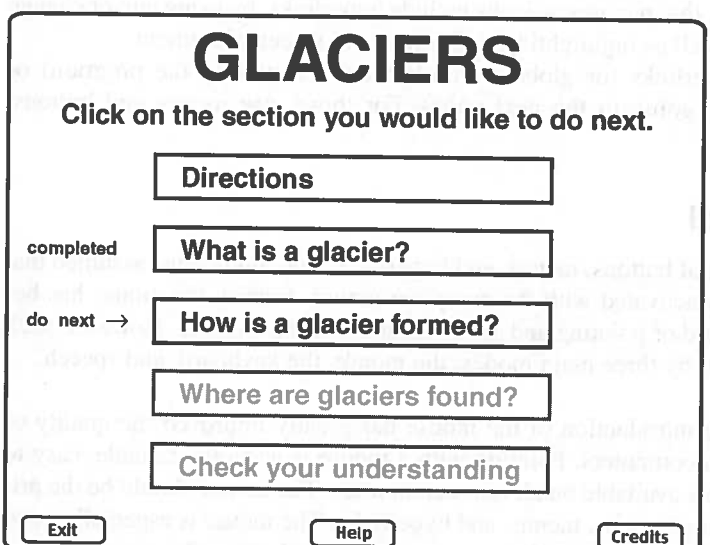

FIGURE 3.6

A Progressive Menu

Review is allowed but not skipping; progress information and advice are also provided.

Hyperlinks Hyperlinks are primarily navigational controls. The most common type is *hot text,* which is colored or underlined text that, when clicked, transports the user to other information, usually on another page. Hyperlinks need not only be text. Icons, pictures, or parts of pictures (e.g., the fifty states on a map of the United States) may be hyperlinks. Invisible areas may be hyperlinks, such as the upper-left corner going to the instructor management functions for a program. In many ways hyperlinks are like buttons. However, buttons have a fairly consistent appearance (rectangles or ovals containing explanatory words or icons), are generally at the bottom of a screen, and are used for any type of control function. In contrast, hyperlinks may appear anywhere on the screen, may look like anything, and are generally used for navigation control.

Hyperlinks are used primarily for the hypermedia methodology (Chapter 5) and on the World Wide Web (Chapter 11). They are now beginning to be found in other methodologies as well. For example, hypertext is being used increasingly to supply word definitions in tutorials, drills, and simulations.

Advantages of hyperlinks are several. They are easy to use. They enable an entirely different style of program navigation—nonlinear hypermedia navigation—which is discussed in Chapter 5. Disadvantages are that they are more difficult to program than buttons or menus, may be visually distracting, are often ignored by learners, and in the case of hyper*text* may conflict with common types of text emphasis such as underlining and boldface. Our general recommendation for hyperlinks follow:

- Avoid *invisible* hyperlinks except for expert users.
- Balance text hyperlinks with *readability* of the text. We recommend that learners be able to turn text hyperlink *cues* (such as text being red or underlined) on and off, so as to make text easier to read.
- Make sure text highlighting techniques (such as boldface) are not confused with hyperlinks.
- Use cursor change, rollovers, and confirmation with hyperlinks, just as with buttons.
- Make it extra clear that pictures or icons include hyperlinks, by using cursor change and rollovers, as well as highlighting techniques and screen placement.
- Avoid use of hyperlinks for global controls (such as quitting the program) or frequent controls (going to the next page). For those, use menus and buttons, respectively.

Modes of Control

In the above discussion of buttons, menus, and hyperlinks, you might have assumed that the controls are always activated with the computer mouse. Indeed, the mouse has become the primary method of pointing and selecting due to its ease of use. However, such controls can be selected by three main modes: the mouse, the keyboard, and speech.

Mouse Control The introduction of the mouse has greatly improved the quality of human interaction with computers. Pointing with a mouse is accurate, reliable, easy to learn and use, and is now available on all microcomputers. The mouse should be the primary mode of controlling buttons, menus, and hyperlinks. The mouse is especially good for novice computer users and nonreaders or nontypists. The keyboard, as we shall see, may be used as a secondary mode of control. There are other pointing devices, such as joysticks and graphics tablets, that are useful for special interactions, such as drawing pictures or controlling objects in games. However, for control using buttons, menus, and hyperlinks, the mouse is the best and most reliable choice.

Keyboard Control In the early days of computer-based instruction, the only method of user control was the keyboard. Learners moved to the next or previous pages with arrow keys or the return key. A program was exited by pressing the ESC (escape) key and the program menu accessed with the Home key if there was one. But keypress control had a number of disadvantages. To distinguish some commands from regular typing (such as typing answers to questions), combination keypresses were often used, such as Control-H for Help. Keyboard commands are not very memorable, so in programs such as simulations or games with many controls, it was difficult to remember what actions on the keyboard performed what functions. The screen was often filled with directions about what keys were active and for what purpose. Keyboard commands resulted in a lot of errors, and learners tended not to use any but the most essential ones.

Although user control has been greatly improved though use of the mouse, keyboard controls do still have a place. They can be a secondary mode of control in addition to using the mouse. For example, a button labeled *next page* may be activated not only by clicking it with the mouse, but by pressing the return key or the right-arrow key. The advantage of such *keyboard equivalents* is that they are preferred by touch typists and expert users. Expert computer users consider mouse control slower and more tiresome than keypresses, which is why applications like word processors always have keyboard equivalents for common user controls, such as Control-S to save. Mouse operations such as buttons and menus are, in general, better for novice users and keyboard operations better for experienced users. But for almost all users, keyboard equivalents are helpful for very frequent actions like going to the next page.

From a design perspective, the issue is how to provide for both inexperienced and experienced users. Once again, knowing the intended users of a program becomes important. The more experienced they are, or the more often they use the program, the more desirable keyboard equivalents are. Very young or inexperienced users benefit more from mouse controls. The best compromise is to provide mouse controls with optional keyboard equivalents for experienced users or novice users as they become more experienced.

A disadvantage of keyboard controls (and therefore of using them exclusively) is that useful techniques like rollovers and confirmation are not easy to implement, as they are with the mouse. They rely more on typing ability and memory so are more prone to errors.

Keyboard commands include not only single keypresses but longer typed commands, such as words and phrases. Extended typing is not as easily replaced by the mouse as are single keypresses. Extended typing is more common for content interactions than for navigation. The main type of interaction which requires extended typing is *searching,* such as typing in a word or phrase, for example, *dinosaurs,* to find the section of a program with information about dinosaurs. Extended typing is also used for commands in simulations and when so many actions are possible that the best way to access them is by typing words or phrases (e.g., "pick up the hatchet"). Even more than single keypresses, extended typing depends on memory and typing skills, and is prone to human error. Like hidden menus, they may be forgotten or ignored by most learners, even when they would be useful. They are inappropriate for very young learners who have not yet learned reading, writing, or typing. However, the useful function of typed commands (such as initiating a search for information on the Web) will soon be possible without any of their disadvantages by virtue of the last user control mode—speech.

Speech Control Speech input is relatively new, not available on many computers, and not yet very reliable. However, it will become more common in the future. We expect reliable speech input and control to be the next great change in computer use, and perhaps an even greater change than the mouse and graphical user interfaces were in the last decade. It will initiate another dramatic increase in acceptance and use of computers by many more people, just as the World Wide Web is doing today. Providing reliable speech input has proved to be very difficult, but, once accomplished, is sure to result in a significant increase in the quality and usefulness of all educational software, not only for user control, but for all types of interaction.

Recommendations for User Control

Let us summarize the more important recommendations for user control and add a few general ones while recognizing that this complex part of design will often have exceptions.

- Use the mouse whenever possible as the primary mode of control.
- Use the keyboard as a secondary mode of control, especially for expert users.
- Use buttons for local controls and very frequent actions.
- Use menus for global controls and selection of program sections.
- Use hyperlinks primarily in hypertext and Web-based programs, and for text controls such as looking up the meaning of a word.
- Strive for control methods that are obvious and easy to use.
- Use cursor changes, rollovers, and confirmation whenever possible.
- Make the position, appearance, and function of controls as consistent as possible.
- Design amount, method, and mode of control in accordance with your users and your content.
- Make controls and directions visible only when activated. Erase or fade them when they are inactive.
- Collect data on how frequently learners use the control features of a program. If certain controls are rarely being used, they may be too difficult to use or simply not useful to learners.

Presentation of Information

Consistency

Techniques for presenting information should be consistent. Readers become comfortable with the conventions of a book or a program, and changes can impede learning. Use conventions that clearly indicate when new topics are being introduced, where to look for directions, or how to answer questions. Following are a few such conventions:

- Put control options, such as mouse buttons, on the bottom of the display.
- Use a consistent prompt for responses, such as "Type your answer here."
- Start a new display for a change in topic and label it accordingly.
- Make it clear when a learner keypress can *add* to a display (e.g., "Click on NEXT for more"), in contrast to *erasing* a display and beginning a new one ("Click on NEXT to continue").
- Use consistent keypresses or buttons for frequent actions, such as the ENTER key to move forward. Many programs cause confusion and errors by switching between buttons and keypresses to move forward.
- Use consistent margin and paragraph conventions.

An overall strategy for consistent screen design is to define *functional areas* for a program (Grabinger, 1993; Heines, 1984). This means allocating sections of the screen to specific purposes, such as directions or orienting information. It is common, for example, to put page numbers and section titles at the top of the display, main program content in the middle, and directions or control options at the bottom, as in Figure 3.7. Unfortunately, this common approach conflicts with the Macintosh and Windows convention of placing pull-down menus along the top line of the display, which is why many designers do not like using pull-down menus unless absolutely necessary. In recent years the trend has been to place many buttons, menus, and hyperlinks all over the display. This is confusing for learners and may well lead to them ignoring most such devices. We recommend simplicity in design, such as placing controls (especially frequent ones) in just one or two places, for example, the bottom and right side (which is our preference) *or* the top and left side. Having frequent controls, such as NEXT, on the bottom right is a benefit because this is where the eyes typically are focussed when finished reading the content.

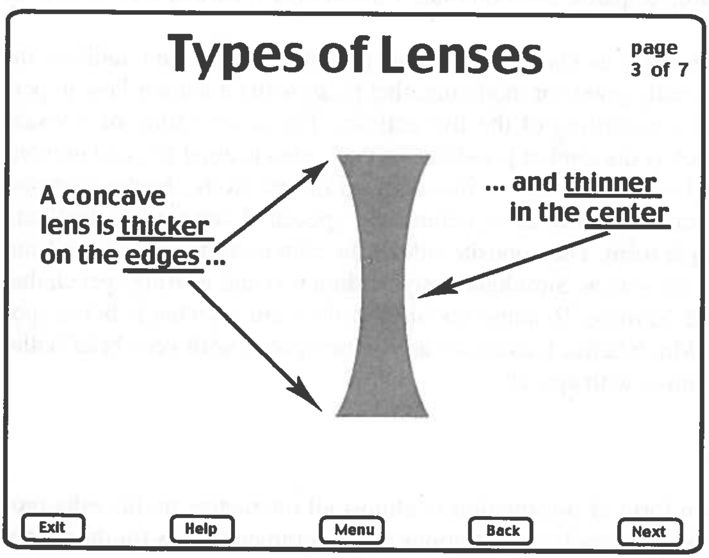

FIGURE 3.7

Typical Use of Functional Areas Orienting information (section name and page numbers) at the top, content in the middle, and control buttons at the bottom.

Modes of Presentation

Mode of presentation defines how information is presented to the learner. Common modes are text, graphics, sound, or video. Text is the most common way to present information, but graphic presentations greatly enhance learning, especially for spatial relationships and for objects or procedures that can be visually depicted. Animations are good for depicting processes in a simplified or abstract way (Hays, 1996), and a computer can do this better than most other media.

Sound is a presentation mode quite different from either text or graphics, both of which are visual. The use of sound in multimedia is becoming much more common. It is used primarily for speech, but also for music and sound effects. Recent advances in computer technology permit easier recording of voice and other sounds for use in programs. This recording is called *digitization,* because the sounds are converted into the digital signals of the computer. *Digitized* sound is easier to produce and more realistic than *synthetic* sound, in which a computer program *creates* artificial sounds rather than playing back recorded, natural sounds. Digitized audio generally sounds better (i.e., is more realistic) than synthetic audio, but consumes more storage space. Most microcomputers have digital sound capabilities built into them or can have them easily added, whereas synthetic sound is less common.

Sound has several advantages. It is necessary when the information itself is of an aural nature, such as learning music or bird calls, or where the learner must be spoken to, as in early reading instruction. Sound is also useful for conveying temporal information such as poetic meter, whereas visual information is better for spatial information such as maps. Sound is good for attracting attention even when the learner is not looking at the screen. Sound has the disadvantage of being ephemeral. The learner cannot generally listen to it at his or her preferred rate, and when it is too fast, the learner can miss something important. When sound is used, the learner should always be able to repeat it as many times as desired. If the sound is long (more than a few seconds), the learner should also be able to pause and continue it like a tape recorder, and be able to repeat or skip it.

Video presentations (such as *QuickTime* movies) combine visual and auditory information. Video is especially good for modeling, that is, showing a learner how to perform some activity with a recording of the live activity. The combination of a visual demonstration with speech is the kind of presentation that video is good for, and demonstrates the power of dual coding theory. As discussed in the previous chapter, complementary forms of information, such as a picture and speech describing it, facilitate learning more than a single form. The opposite side of the coin is conflict resulting from the improper use of dual messages. Simultaneously reading text and hearing speech that is identical may decrease learning. Reading text *almost the same as* what is being spoken can be even worse. Much better techniques are to use speech with very brief bullet points or to describe pictures with speech.

Text Information

Text is the most common form of information in almost all interactive multimedia programs intended for learning. Several considerations and recommendations for the proper design of text are important for all multimedia methodologies.

Text Layout and Format Because text is a major component of most interactive multimedia, its proper design is essential. If there is a particular sequence in which text information should be read, follow the general convention of sequencing from the top to the bottom and left to right because users are used to reading in that way. Sentences and paragraphs should be well formatted. This means that lines should not end in the middle of words, and that paragraphs should not begin on the last line of the display or end on the first line of the next display. Consistent use of indentation or blank lines to indicate new paragraphs should be used. Text should not be squeezed into half of the display, leaving the rest almost empty. These are the same considerations that should be used for text on paper, but authors of computer programs often do not show the same concern for well-formatted text. Figures 3.8 and 3.9 illustrate a poorly formatted and a well-formatted display.

Spacing between lines effects text readability. Most modern software allows control over *leading,* the space between successive lines. When available, it should be adjusted to make text readable and attractive. Newer microcomputers are better in this regard. Built-in text fonts generally adjust line spacing according to the text font and size, making it attractive and easy to read.

Figures 3.8 and 3.9 illustrate a number of the format considerations that have been discussed. Figure 3.8 contains text that is in all uppercase, single-spaced format; is crowded to the left side of the display; contains words split across lines; uses inconsistent paragraphing conventions; and ends the page in the middle of a sentence. The buttons are also poorly aligned. Figure 3.9 corrects all these errors, leaving a display that is more aesthetic and much easier to read.

The relationship of text and graphic information is important. When a combination of text and graphics appear on a display, it is useful to enclose the text in a box, as in Figure 3.10. Many other ways of emphasizing segments of text are available, as illustrated in Figure 3.11. Underlining and alternative typefaces are common methods, but

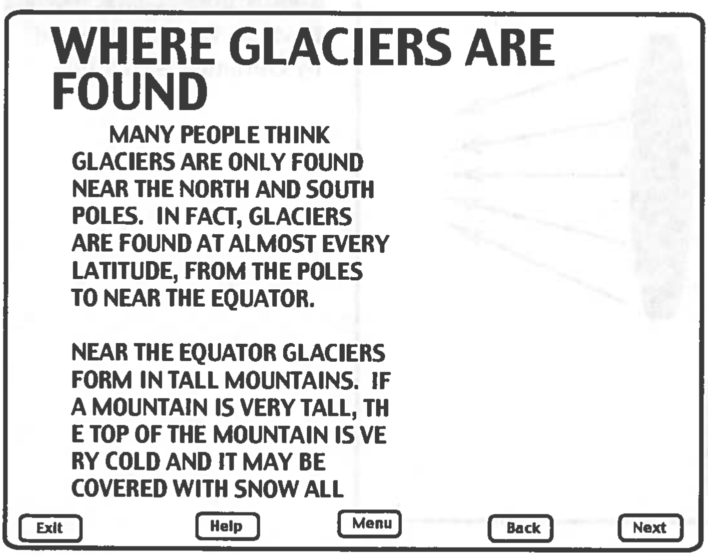

FIGURE 3.8
A Poorly Formatted Display

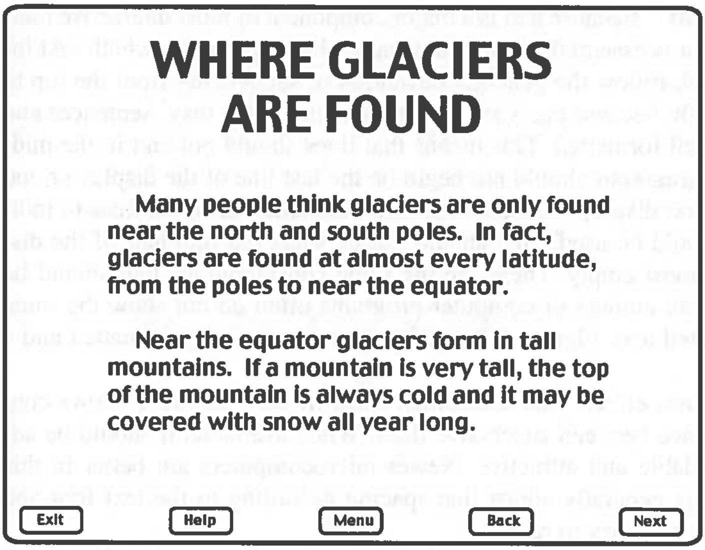

FIGURE 3.9

A Well-Formatted Display

not particularly effective. Because underlined and colored text are now commonly used to indicate *hypertext* (text that when clicked branches users to a new location), using these techniques for emphasis should be avoided. Otherwise users may be misled into thinking that this text can be clicked for navigation. Blinking or moving text (not illustrated) should never be used. These annoying techniques make text very difficult to read. Text that is all uppercase is also difficult to read. More effective methods of emphasis are boxes, arrows, larger letters, and isolation (Figure 3.12). Remember that any emphasis technique should be used in moderation or it will cease to be effective.

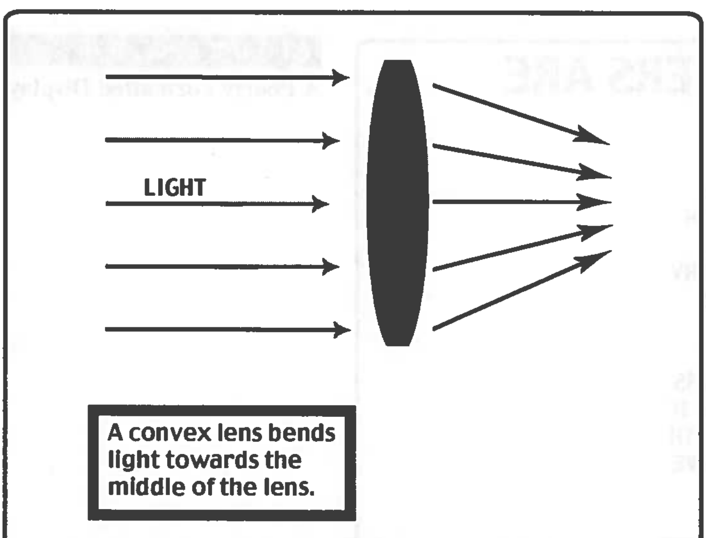

FIGURE 3.10

Block of Text Emphasized by Outlining with a Box

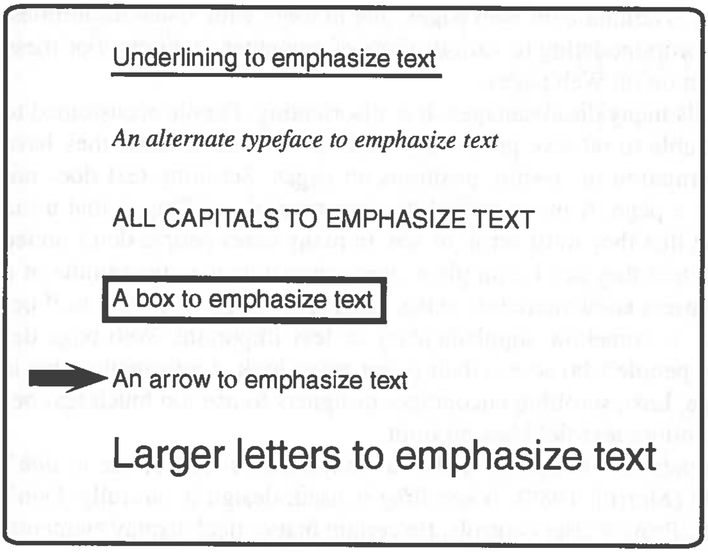

FIGURE 3.11
Methods of Emphasizing Text

The most difficult design issue regarding text is the use of scrolling, which has become common in hypermedia programs and Web pages. Scrolling occurs when all the information cannot fit on the content portion of the screen at one time. To view all the information, the user has to scroll up or down to see it, causing other information to disappear from the screen. Both text and graphical information may scroll. Usually a scroll bar or other controls allow the user to move up and down at will.

Scrolling provides several advantages. It requires fewer screens to present information. Scrolling fields are more accommodating to users who change size or other

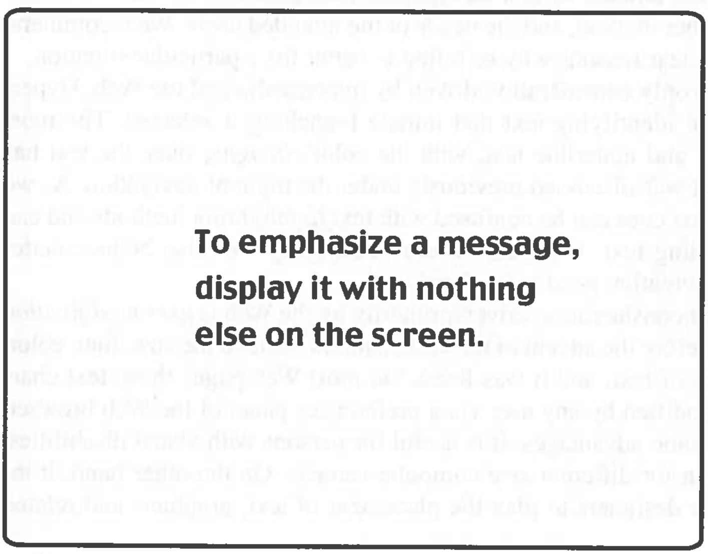

FIGURE 3.12
Emphasizing Text by Isolation

characteristics of text, as is common on Web pages, and to users with visual disabilities. Scrolling is also more accommodating to various sizes of computer monitors. For these reasons scrolling is common on Web pages.

Scrolling also entails many disadvantages. It is disorienting. People accustomed to the layout of books are able to retrieve previously read information because they have learned to look for information in specific positions on pages. Scrolling text does not have a fixed position on a page. A more critical disadvantage of scrolling is that users often *ignore* information that they must scroll to see. In many cases people don't notice scroll bars and think the text they see is complete, even when it ends in the middle of a sentence. In other cases users know more text exists, but choose not to access it, as if believing the text "below" is somehow supplementary or less important. Web page designers report that many people who access their pages never look at information that is not at the top of the page. Last, scrolling encourages designers to use too much text because the length of a scrolling text field has no limit.

Therefore, if information is important and you want users to read or see it, *don't* put it in a scrolling field (Merrill, 1988). If scrolling is used, design it carefully. Don't use it for very short texts. Provide user controls. Be certain that critical display elements, such as user controls and orienting information, do not scroll out of view.

The alternative to scrolling is paging, going forward or backward an entire page (screen) at a time, as in a book. Paging allows each page to be well designed, with the position of text and illustrations nicely coordinated. Paging is more natural and comfortable to most people. The main disadvantage of paging, and the reason for the increasing popularity of scrolling, is the great variation in monitor size and the fact that the viewable window for most software, such as Web browsers, can be dynamically changed by any user. When the user changes window size, the information a designer planned for a page may no longer fit properly. In contrast, scrolling text automatically reformats to fit within the constraints of the current window or monitor.

The relative advantages of paging versus scrolling are obviously complex. The designer should consider the amount of text and graphic information, whether it is delivered via the Web or another method, and the needs of the intended users. We recommend paging unless there are clear reasons why scrolling is better for a particular situation.

Scrolling is not the only consideration driven by hypermedia and the Web. Hypertext *cues* are methods of identifying text that initiate branching if selected. The most common cue is to color and underline text, with the color *changing* once the text has been selected. Hypertext was discussed previously under the topic of navigation. As we said at that time, hypertext cues can be confused with text highlighting methods and can impede the ease of reading text. It should be used cautiously. We also believe better methods of hypertext navigation need to be developed.

Another text format consideration driven primarily by the Web is *user modification of text characteristics*. Before the advent of the Web, authors decided the size, font, color, and other characteristics of text, and it was fixed. On most Web pages those text characteristics may all be modified by any user via a preferences panel of the Web browser. User modifiability has some advantages. It is useful for persons with visual disabilities. It allows accommodation for different size computer screens. On the other hand, it increases the difficulty for designers to plan the placement of text, graphics, and related screen elements.

Text Quality The following are important factors in the quality of text:

- Leanness
- Transitions
- Clarity
- Reading level
- Mechanics

Leanness (Burke, 1982) describes an important quality of text often recommended for programs intended for learning. It means a program should say just enough to explain what is desired, and no more. This applies not only to text descriptions, but to examples of concepts, sample applications of rules, pictures for demonstration purposes, and so on. In support of lean presentations, Reder and Anderson (1980) demonstrated that readers learn the main points of a textbook better from summaries of the main points than from the text itself. This was true even when the main points in the textbook were underlined.

In addition to such evidence, learners obviously require less time to study a more succinct program. Furthermore, validation and revision of a lean program is easier. If you evaluate a long program and find that it is effective, you do not know what parts of the program were most responsible for learning. Shortening the program to increase its efficiency is difficult. If a lean program works well, however, you have no need to shorten it. If it is *not* effective, you have less concern about adding material to improve it. Although lean presentations have benefits, the amount of detail must vary considerably for different instructional purposes and methodologies. Hypermedia reference materials, such as CD-ROM–based encyclopedias, naturally have much more text detail than tutorials or drills.

Transitions from one topic to another are essential because maintaining a clear flow of ideas in a multimedia program is more difficult than in a textbook. Limited display capacity requires changing pages more frequently. It is difficult for a learner to distinguish a change in display that represents a continuation of a current topic from one that represents changing to an entirely different topic—the equivalent of changing chapters in a book. A good program uses clear transition statements such as, "Now that you know what glaciers are, we discuss the way in which they are formed." Similarly, reading is facilitated if a program distinguishes whether a keypress or mouse click causes a continuation of a topic or a change of topic. Contrast two directions. The first one is vague whereas the second one provides both *functional* and *cognitive* direction:

Click here to continue.

Click here for the next section: HOW GLACIERS ARE FORMED.

Clarity of text is facilitated by avoiding ambiguous language and by having consistent use of terminology. Ambiguity occurs frequently in technical areas, in which specific technical terms have come into everyday usage with less specific meanings. Pointing out that such terms are being used in their technical sense may be necessary so learners do not assume the common usage. Ambiguity is also caused by using pronouns with unclear referents. Consider the following directions from a chemistry laboratory. "The liquid is then poured into a beaker. It must be heated." It is not clear whether the liquid is heated before being poured into the beaker, or if the beaker is supposed to be heated before the liquid is poured into it, or if heating takes place after pouring.

Using consistent terminology means two things. First, more than one word should not refer to the same thing, such as sometimes using *beaker* and other times *container*. The reader may ascribe significance to the subtle difference between the two. Second, the same word should not be used at different times to mean different things, which also produces ambiguity.

The *reading level* of a program must be suited to the learners who use it. It is common to find programs for learning beginning arithmetic, to be used by children in the first grade, with directions and questions at the third-grade level. Readability formulas may be used to determine the approximate reading level of a program or segments of it. However, piloting with real learners is a more reliable method of ensuring the correct level of text.

Mechanics is a characteristic of text quality that *should* not be a factor at all. It refers to the use of correct grammar, spelling, and punctuation. Unlike clarity, standards for mechanics have been established, and it remains only for writers to follow them. When a program has poor mechanics, learners view the author of the program with less credibility and do not take the instruction as seriously. They may also learn poor mechanics themselves.

Graphics and Animation

Modern multimedia programs make extensive use of pictures, illustrations, graphs, and animations, though they are not always designed or used well. When properly used, pictorial information enhances learning. However, if used improperly, it can be detrimental (Dwyer, 1978). An overriding consideration for the effective use of graphic information is the importance of the information presented. A learner is generally attending to *something*. Attention should be focused on the important information in a program rather than incidental information. Pictures, especially animated ones, capture attention more than text. Thus, graphic presentations should be designed for the more important information (Szabo & Poohkay, 1996). Unfortunately, authors frequently create graphics that are artistically excellent but illustrate points incidental to the learning objectives.

In designing and using graphics, one should consider both the *purpose* of the graphic information and the *type* of graphic. Graphics may be used in programs in many ways. Four primary uses of graphics during the presentation part of a program follow:

- As the primary information
- As analogies or mnemonics
- As organizers
- As cues

Figure 3.13 shows a presentation in which a picture is the source of primary information. To explain what a triangle and its parts are without pictures would require textual

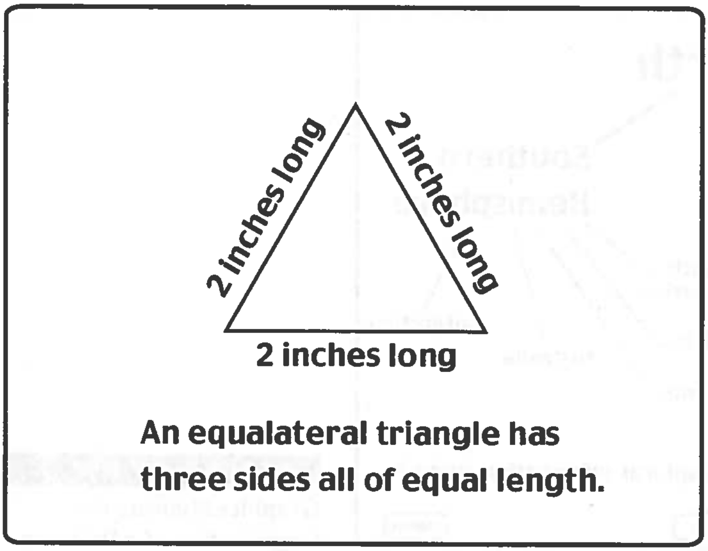

FIGURE 3.13
Graphics as the Primary Information in a Program

explanations beyond the reading ability of most children. The more visual and spatial the content to be learned, the more integral graphic presentations should be.

Graphic analogy (Rigney & Lutz, 1976) is illustrated in Figure 3.14. The picture of the mountain is a way of making the main concept, concavity, clearer and more memorable. This type of visual technique is especially useful for concepts difficult to remember or understand. Abstract ideas are easier to understand if the learner can visualize them.

Graphics such as maps, timelines, flowcharts and organizational charts are useful for showing the layout of a topic, a program, or a section of either (Figure 3.15). In social

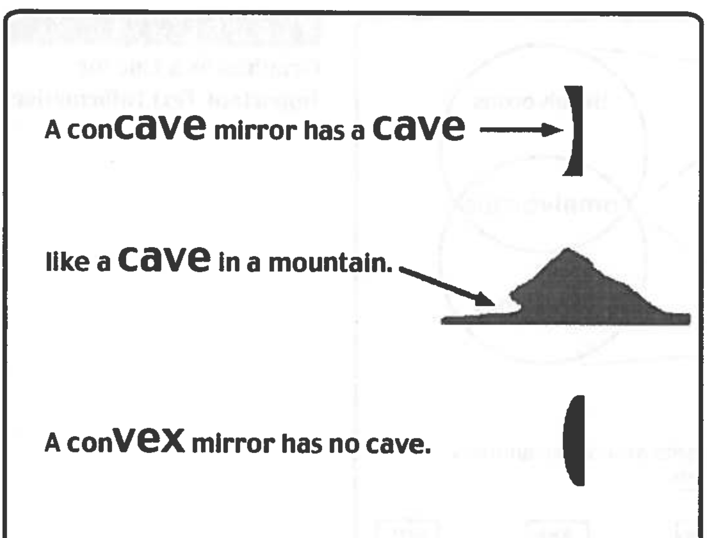

FIGURE 3.14
Graphic Analogy

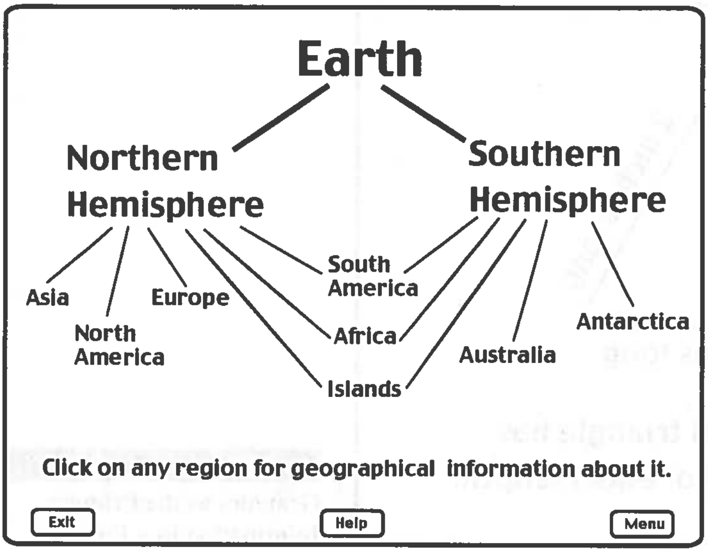

FIGURE 3.15
Graphics Showing the Organization of a Program

studies programs about countries or regions, a map of the region is often used both to illustrate program structure and to allow navigation (by clicking on parts of the map).

Figure 3.16 shows graphics used as a cue or emphasis technique, focusing attention on important information. Other uses of graphics are illustrated in the chapters about other multimedia methodologies, such as the use of graphics in questions and feedback during tutorial programs.

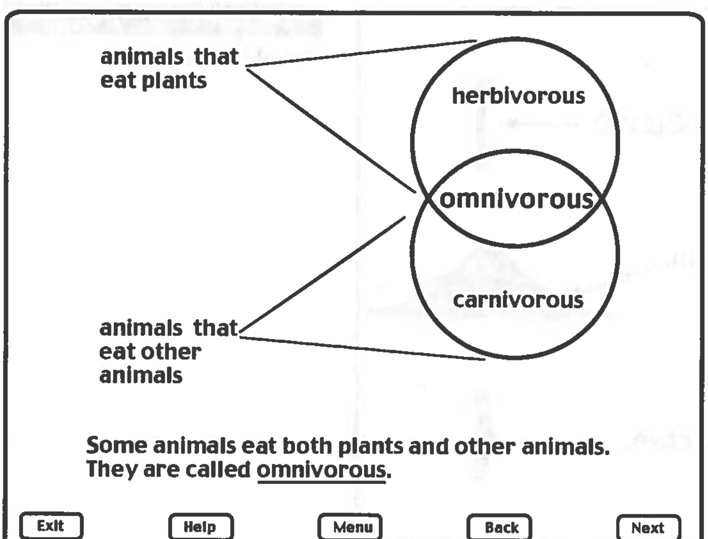

FIGURE 3.16
Graphics as a Cue for Important Text Information

There is wide variety of *types* of graphic information. The main ones in interactive multimedia are, in order of increasing complexity:

- Simple line drawings
- Schematics
- Artistic drawings
- Diagrams
- Photographs
- Three-dimensional images
- Animated images

Designers should be familiar with all the types of graphics and choose one that is appropriate for each purpose. Following are some general recommendations about the proper use of graphics.

Select and design graphic information consistent with and integrated into the rest of the instructional message. For instance, a program teaching about the refrigeration cycle (used in air conditioners and refrigerators) is enhanced by a diagram oriented in a circle to emphasize the cyclic nature of that process (Figure 3.17).

Avoid excessive detail or realism. Details can overload memory and confuse the learner, who will not know what to focus on. Realistic pictures contain more details than simplified ones. Simple line drawings may demonstrate a point more clearly than realistic pictures (Dwyer, 1978). This has become very relevant now that multimedia designers can easily incorporate realistic photographs (using scanners or digital cameras) into multimedia programs. Certainly realistic photographs are necessary in some cases (programs on art history, for example). Realistic images may improve a program in terms of overall look-and-feel (which may demand photorealism) or motivation.

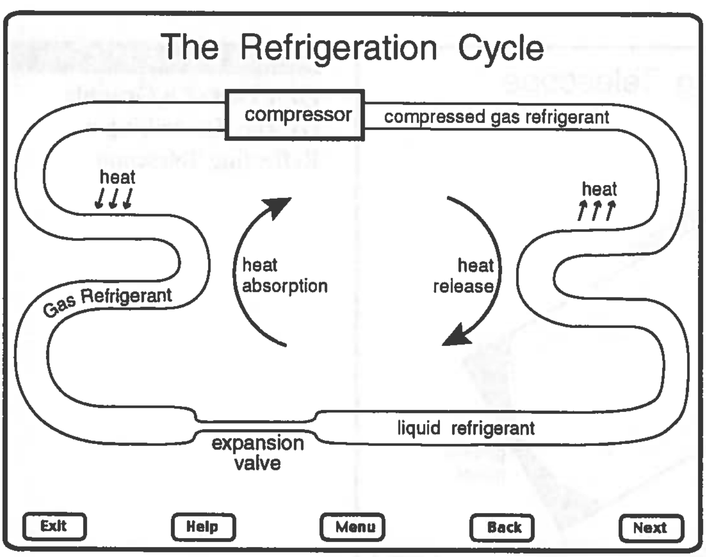

FIGURE 3.17
Graphic Depicting the Circular Nature of the Refrigeration Cycle

Those considerations should be weighed, however, against the increase in complexity and the potential for distraction.

Consider breaking complex illustrations down into simpler ones. It is not as easy to break up graphics as it is text. One way to do so is to produce *part* of a graphic, allowing the learner to inspect or read about it first, and then to *overlay* new parts or details, gradually building up a large or complex image. Figures 3.18 through 3.20 show a series of pictures in which the parts of a telescope are overlaid and described one part at a time.

Use animation when dynamic change is important and allow the learner to pause, continue, repeat, and in some cases control the speed of change. Allow learners to control the amount of time they look at graphic presentations. Pictures should not disappear after a specific number of seconds, but only when the learner presses a key indicating readiness to go on. Present pictures and related text *simultaneously,* so the learner can inspect the illustration and the explanation together. If possible, explain pictures with *speech* rather than with text, providing learners the ability to pause, continue, and repeat the speech.

Video

Video, such as of QuickTime movies, is becoming common in interactive multimedia. Video can take many forms: a soundless demonstration of a procedure, an unseen narrator describing the visual activity, cartoons, a person or people speaking (such as an interview), comedic and dramatic plays, and so on. Very realistic animations are sometimes used when the real event cannot be captured, such as the inner workings of an automobile engine.

The use of video has opened many opportunities for educational multimedia. Dramatizations encourage people to evaluate their attitudes and thus are useful to effect attitude change. A narrator explaining how to operate a complicated device is more effective than reading a text passage about it. Video can be engaging, entertaining, and thought provoking. It can lend a very professional look to a program. A short video can replace long convoluted text passages. Video is a natural choice for some learning ac-

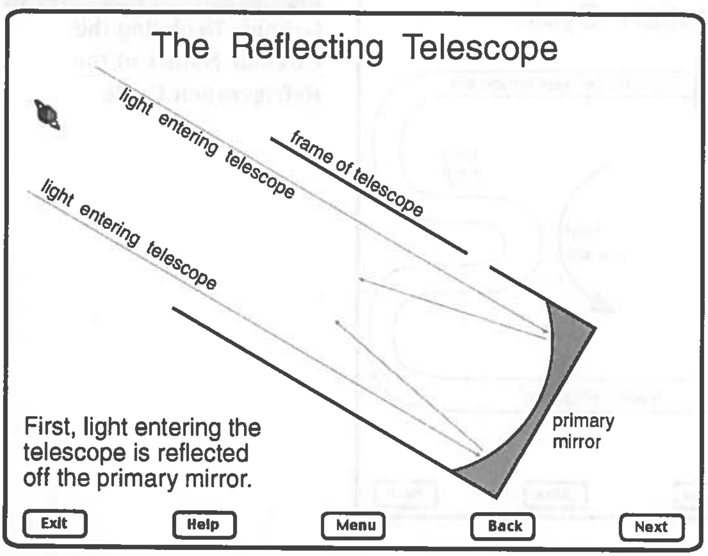

FIGURE 3.18

First Part of a Graphic Overlay Describing a Reflecting Telescope

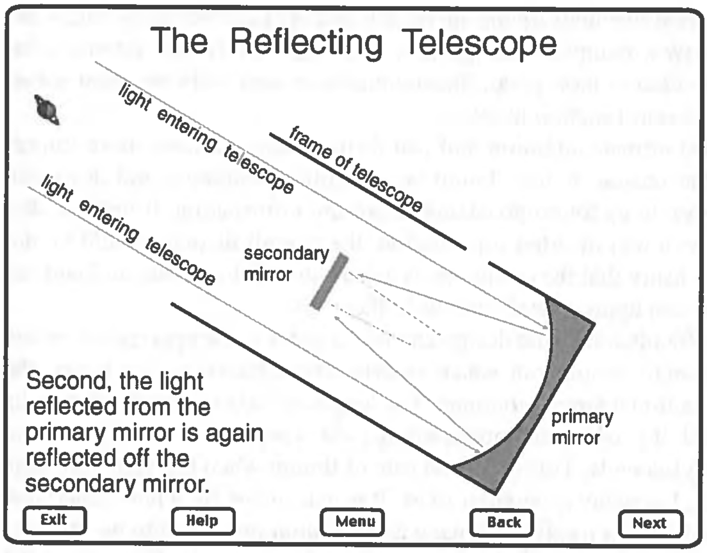

FIGURE 3.19
New Graphic Information Added to the Display

tivities, such as conversation in a foreign language or analyzing news events in social studies. Information presented by video may be more memorable due to its visual detail and its emotional impact (Swan, 1996).

Designers must also be aware of the costs and potential pitfalls of video. Creating video material is expensive and time consuming. Producing quality video with actors, sets, and professional cameramen can cost several thousand dollars per minute of final video. The cost of video can sometimes equal all the other costs of the rest of a program's development. If shortcuts are taken and poor video is produced, it can damage the professional look of a program more than the absence of video.

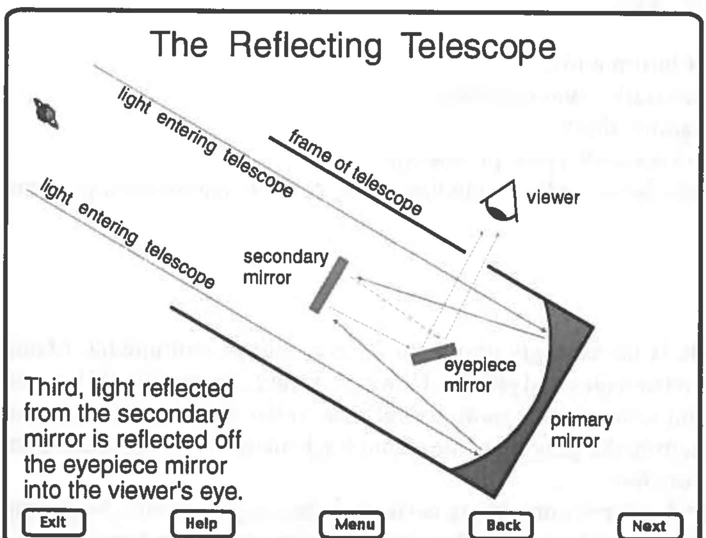

FIGURE 3.20
More Graphic Information Added to the Display

Video also places great demands on the speed and display capabilities of hardware. Fast processors, hard drives, compact disk players, and high bandwidth Internet connections are needed for video to look good. Special hardware and software must sometimes be installed for video to function at all.

Like graphics, video attracts attention and can distract learners from more important information. For that reason its use should be carefully considered and designed. When video is used, it should be for emphasizing important information. If video is displayed simultaneously with text or other information, the overall display should be designed and evaluated to ensure that the components are meaningful together and laid out in a way that the learner can appropriately attend to them all.

An important but difficult area in the design and use of video is the appropriate *length* of video segments. Although people can watch entertainment television for hours, the same is not true for instructional video programs. The length of video depends a lot on its content and how it is used. It is often recommended that video segments in multimedia be limited to twenty to thirty seconds. This is a good rule of thumb when the video presents instructional information, but many exceptions exist. It is reasonable for a news interview to be longer, whereas watching a foreign language conversation may need to be shorter.

Like animations, it is critical that users have control during video. First, the usual global controls of a program (quitting, reviewing, going to a program menu, changing the volume) should still be accessible during video presentations. This is often difficult to program (a weakness in many multimedia authoring tools), so many programmers simply *disable* user controls and claim (incorrectly) that learners should not use controls during a video. That, of course, is just laziness. Important global controls should always be accessible.

Secondly, a video presentation should always have its own controls. At the very least the learner should be able to pause, continue, replay from the start, and control volume. Less critical but sometimes useful controls are scanning forward and backward, and jumping directly to particular sections. The longer a video presentation, the more necessary scanning and jumping become. The following list summarizes some recommendations for the use of video:

- Use it for important information.
- Use video for demonstrating and modeling.
- Keep video presentations short.
- Consider the great expense of video production.
- Provide user controls during video, including video controls and general program controls.

Sound

Sound, especially speech, is increasingly important for educational multimedia (Mann, 1995). Like video, it has advantages and pitfalls. However, sound can and should be used much more than it is, and is frequently more useful than video. In many instances in video presentations in multimedia programs, the sound track alone is the important part, and the visuals are just for show.

Sound is necessary for some content areas (foreign languages, music, beginning reading). Sound is excellent for gaining attention, even when the learner is distracted and not even looking at the display. When a learner goes to a display where new or special directions are needed, using speech for *directions,* or just to tell the learner what to do is a useful technique. Text directions are often ignored. Furthermore, when textual content is displayed on the screen, speech is a useful way to distinguish *directional* verbal information (speech) from *content* verbal information (text). Speech is useful for nonreaders, poor readers, young children, people who speak a different language, and for the visually impaired. For some users, it is best provided as a user-controlled option, for example, providing an optional audio track for visually impaired learners.

The costs and pitfalls of using sound are similar to those of video. Audio production is not as expensive as video production (which generally includes audio) but is certainly more expensive than text production. Producing quality audio (devoid of background and microphone noise and tone or volume fluctuations) can be more difficult than producing the visual part of a video program. It is best to use professional speakers, to rehearse speech before recording, to use good recording equipment, to record in an area with good acoustics, to have consistent volume and tonal settings for all sound files, to edit and digitize well, and to evaluate carefully the quality of the final product.

Like video, user control is essential. Once again, the user should have access to the usual controls of a program even when sound is playing, and should at a minimum be able to pause, continue, change the volume, and replay sound segments as much as desired before continuing. Scanning is not as useful with audio as with video, but being able to jump directly to sections during longer audio presentations can be useful.

Presentations containing identical speech and text are common. This would seem to be beneficial as it gives the learner the choice of reading or listening, and might be especially useful for learners with visual or auditory impairment. But identical speech and text can be distracting and actually impair learning. It is better to provide controls that encourage learners to use *either* the text or audio presentation, not both at the same time. For example, clicking a closed caption icon may automatically disable the audio, or turning the audio volume all the way down may automatically initiate closed captioning. In some cases a user may want to override automatic features and independently control both captions and volume.

For good readers, listening to speech is slower than reading. Many people also have a personal preference (a learning style) for either reading or listening. Therefore, if your expected learners are adults and if a program contains extensive verbal information, the option to choose speech or text is much better than providing just one or the other.

Many programs use speech (or other sounds) in only a token fashion, such as music or speech on the title page. Multimedia programs can be greatly enhanced with audio, but only if incorporated carefully with high-quality audio, good user control, and appropriate content. Following are summary suggestions for the proper use of audio.

- Use speech for getting attention, for directions, and for dual coding.
- Provide speech for users who have difficulty reading text.
- Provide both text and speech as options.
- Use audio for appropriate content areas, such as language learning.
- Allow user control of audio (pause, continue, repeat, skip, and volume).
- Allow the usual program global controls even during audio segments.
- Do *not* use token audio in just one or two places.
- All audio must be of high quality.

Color

The use of color is closely akin to that of graphics. Although evidence demonstrates that color enhances learning and motivation (Dwyer, 1978; Pett & Wilson, 1996), it does not seem to be as powerful as some other techniques, such as animation (Baek & Layne, 1988). Also, like graphics, color can be easily misused so as to be ineffective or even detrimental. Like most factors, the successful application of color is affected by individual differences (Dwyer & Moore, 1992).

Consider first some of the advantages of color. It is effective for attracting attention, though only when used in moderation. The attention-getting effect of color can and should be used, like that of graphics, to attract attention to *important* information. For example, a program may present corrective feedback in bright green. However, this technique can be easily overdone. It would probably be ineffective to design a program in which primary information is displayed in green, corrective feedback in yellow, directions in red, hints in blue, and section titles in orange. The learner may forget what each color represents and simply ignore them. In addition, the overall display would appear garish.

Color may increase the information capacity of a display and be used to emphasize differences. Imagine a graph with lines showing the effect of the economy on the earnings of several businesses. With more than five lines it is difficult to distinguish one line from another. Using dotted, dashed, crossed, and other types of lines may simply increase the visual difficulty. Colors can make the lines easier to distinguish and associate with a legend.

Consider also the potential pitfalls of using color. Information may be lost on learners who have visual color deficiencies—about one person in fifteen. Similarly, color information may also be lost on some displays and when printing. When possible, therefore, use color as a *redundant* cue. This means when using color to convey information, try to convey the information in a second fashion as well. If lines on a graph are drawn with different colors, also label them with text. Redundant information can be user controlled (a button to display or erase textual labels on a graph) in the same way learners can use closed captioning to help with auditory impairment. An obvious exception to the redundancy suggestion is when the objective of the program relates to color, as in an art program. Such a case makes it difficult to convey the essential information in any way other than with color.

When making color design decisions, one must strike a compromise between attitudes and learning. Most learners find a program in black and white "old fashioned" and dull, even if it communicates information effectively. Users generally prefer the colors red and blue, although they are poor choices for text and detailed pictures because colors at the extreme ends of the visible spectrum—the reds and blues—are perceptually difficult to process and should be avoided for text and detailed pictures. Some colors, especially those near the center of the visible spectrum such as yellow and green, are easier to perceive than others (Durrett 1987; Silverstein, 1987). Furthermore, some color combinations (for background and text) are better than others. One should avoid red with green, red with blue, blue with yellow, and blue with green. More than four simultaneous colors should be avoided (Smith, 1987), especially for beginning learners.

The use of color should be consistent with common usage in society. Do *not* use green to mean "stop" or red for "go," which could result in errors. Do not show financial graphs in which red indicates profits and black indicates losses. Our main suggestions are based primarily on learning effectiveness. You may need to temper them with considerations of learner affect. Many excellent suggestions for the proper use of color are made in

Shneiderman (1998); you can consult Durrett (1987) for a general discussion of the theory and use of color on computers. Consider some suggestions from these sources:

- Use color for emphasis and for indicating differences.
- Ensure good contrast between foreground and background colors, especially for text.
- Use only a few colors for color coding.
- Allow learner control of color coding.
- Use colors in accordance with social conventions.
- Be consistent in the use of color.
- Test programs on noncolor displays to assess their effect on persons with color vision deficiency or with older equipment.
- Balance learner affect and learning effectiveness when using color.

Providing Help

Learners should always be able to get help. They frequently need help of two different types, procedural and informational. Procedural help should *always* be available. It refers to help for operating the program, such as changing the speaker volume. This information may be provided in the initial directions or may be obtained throughout the program by clicking a help button. A useful technique is to provide help through *rollovers.* A rollover, discussed earlier in the section on buttons, is visual or auditory information occurring when the learner points at (but does not click) something on the screen. For example, pointing at an icon may display an explanation of what happens if you click on that icon. Rollovers provide reminders of what various controls and other screen options do or how to use them. They are a form of help on demand. If users forget what the icons do, they need only point at them to be reminded.

Informational help means help with the content. This includes accessing more detailed descriptions, additional examples or sample problems, or explanations worded more simply. Other types of informational help include glossaries, references, and diagrams. Although a program should always provide procedural help, provision for informational help depends on its methodology, content, goals, and difficulty. Informational help may be more appropriate in hypermedia or tutorials and less appropriate in drills or exams.

If help of either sort is available, it must be easy for learners to access, and learners must know that it is available. If a learner does not remember how to get help, its usefulness is lost. Rollovers and help buttons, which are easy to use and obvious when available, are recommended over keypresses or pull-down menus, which are more easily forgotten.

Our general recommendations for providing help are

- Always provide procedural help.
- Provide informational help depending on the program's purpose and methodology.
- When providing informational help, try to make it specific to the content being dealt with (context-specific help).
- Allow return to directions at all times.
- Provide help via rollovers for functions available at any particular time.
- Always have a help button or menu *visible,* reminding learners that help is available.
- Provide help in a *print* manual for *starting* a program. Online help is not useful if the user does not know how to start the program.

Ending a Program

It is useful to distinguish between ending a program *temporarily,* such as when the user leaves but intends to return later, and ending it *permanently,* when all required parts have been completed or, for other reasons, the user is not likely to return. Temporary endings and the option to leave temporarily apply to *every* type of program and should *always* be available. Some programs do not have an option to exit at certain points because designers do not want learners to leave at certain points. However, it is hopeless and perhaps silly to try to prevent learners to stop working. They can turn the computer off or just walk away from it. It is much better to give users the ability to exit "officially." Doing so improves their attitude (for it gives them a greater sense of control) and allows the program to perform a proper exit, for example, storing data and reminding the user what to do when returning to the program.

If you want learners to be able to restart where they left off, a program must either store data to do that automatically or give the learner directions indicating how to return to the point he or she left off, such as through a menu (Figures 3.21 and 3.22). When a program automatically keeps track of where the learner is at termination, it contains *passive bookmarking.* If the program allows the learner to personally flag parts of the program for whatever reason, it contains *active bookmarking.* Programs that last longer than fifteen minutes (approximately) should provide passive bookmarking or some other method to continue near the point where the user exited.

Permanent ending signifies *completion* of a program, although the meaning of completion varies for different program purposes and methodologies. Permanent ending applies well to some types of programs (tutorials, drills, tests) but less or not at all to other types of programs (simulations, hypermedia, tools). When a program is about to end permanently, it may provide summary statements about the information in the program. A

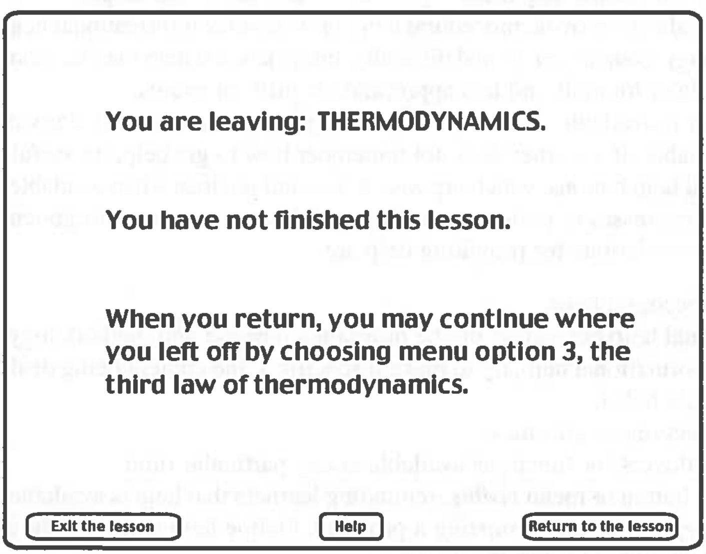

FIGURE 3.21
Giving the Learner Information for Returning at a Later Time

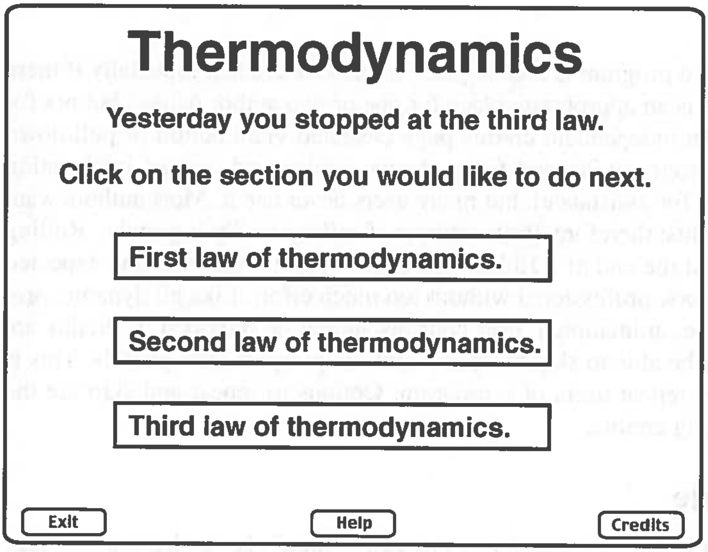

FIGURE 3.22

A Menu for Restarting at the Point the Learner Previously Exited

summary might be a list of major points or a paragraph summing up the purpose of the program. If the program has been collecting data about learner performance, the learner may be given a summary of performance and recommendations for further study. A permanent ending may also give a statement of transition into programs that follow. Most commercial programs, however, attempt to be independent of other programs and provide no such transition statements. Programs that are part of larger curricula are more likely to include them.

According to some educators, after presenting all its information, a program should provide activities to enhance retention and transfer of learning (Gagné et al., 1981; Wager & Gagné, 1988). Different instructional methodologies are appropriate to different goals, such as initial learning (for which tutorials are often used), retention (for which drills are often used), and transfer (for which simulations are often used). Multiple instructional methodologies need not be in separate programs. A single program may contain a tutorial section, followed by a drill or simulation section, and end with a self-test. However, it is beneficial to keep instructional activities relatively short (twenty or thirty minutes) and within that timeframe, it is difficult to introduce new material *and* to enhance retention and transfer. We do not believe the important goals of retention and transfer can be accomplished well when squeezing them into the final segment of a program.

Safety Nets

It is easy for users to accidentally click on a QUIT button or menu, thus going unintentionally to the closing of a program. It is always good to provide a *safety net,* which allows the user to rescind the request to exit, returning instead to where they were in the program. We recommend a safety net that simply *overlays* the display the user is viewing at the time of initiating (perhaps accidentally) an exit. That method preserves user orientation and is also easy to program.

Credits

The closing sequence of a program is a good place to provide credits, especially if there are many. The title page is an appropriate place for one or two author names, but not for a more extensive list. An independent credits page (selected via a button or pull-down menu anyplace in the program) is good for extensive credits and contact information (such as where to phone for assistance), but many users never use it. Most authors want learners to see some credits; therefore, the technique of *rolling credits* is popular. Rolling credits, like those used at the end of a Hollywood movie, are a traditional and expected type of ending and can look professional without too much effort. Like all dynamic presentations (movies, voice, animations), user controls should be provided. If credits are long, the learner should be able to skip them and quit the program immediately. This is especially important for repeat users of a program. Options to repeat and skip are the most important for ending credits.

The Final Message

When ending temporarily or permanently, a program should always have a message making it clear that the user is leaving the program. Figure 3.23 illustrates such a message. Many programs do not provide one. Often, the last piece of information presented in the program is left displayed on the computer screen, giving the impression that the program is not really over. It is important to clean up the display at the end. Any text and pictures should be erased, and the final message displayed.

Exiting the Program

Clicking the *exit* option after the final message should take the learner to an appropriate place. Usually, the most appropriate place is where they were just before beginning the program. If learners enter the program from a system or curriculum menu page, that is

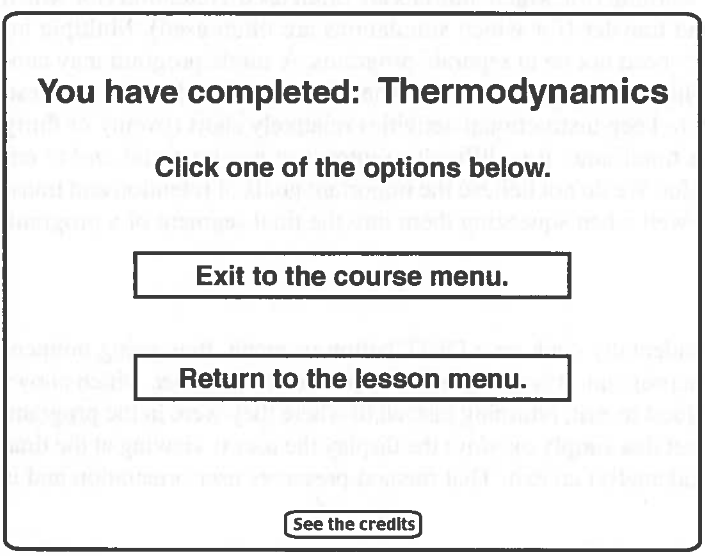

FIGURE 3.23
The Final Message

where they should return. If they enter the program by clicking a desktop icon from the operating system, they should return to the desktop. If the program is one in a predetermined sequence of programs, learners may proceed to the next program in the sequence. In that case, the learner should be allowed to choose whether to continue to the next program immediately or to return and begin the next program at a later time.

Recommendations for Ending a Program

Our general recommendations for the closing and exit sequence of any program are the following:

- Provide the ability for the user to exit *anywhere* in a program.
- Ensure that a temporary exit is always available with user control.
- Provide a safety net to rescind a request to exit.
- Provide closing credits with user control.
- Provide a final message making it clear the user is leaving the program.
- Return the user to an appropriate place after the program quits.

Conclusion

The factors we have discussed in this chapter are general ones that apply to practically all software for learning and instruction. The chapters to come discuss new factors specific to each methodology and expand on those in this chapter, making additional recommendations appropriate to each methodology. Familiarity with these factors has two purposes. It provides a basis for reviewing and evaluating instructional programs you buy, and it provides a basis for designing your own programs. Designers may not always want to follow our recommendations, because of exceptions specific to subject areas, learning goals, and user characteristics. However, all designers should be familiar with these factors and their influence on learning and should make *deliberate* decisions about them when planning a program.

REFERENCES AND BIBLIOGRAPHY

Ayersman, D. J. (1995). Effects of knowledge representation format and hypermedia instruction on metacognitive accuracy. *Computers in Human Behavior, 11*(3-4), 533–555.

Baek, Y. K., & Layne, B. H. (1988). Color, graphics, and animation in a computer-assisted learning tutorial lesson. *Journal of Computer-Based Instruction, 15*(4), 131–135.

Black, J. B., Swan, K., & Schwartz, D. L. (1988). Developing thinking skills with computers. *Teachers College Record, 89*(3), 384–407.

Borg, W. R., & Schuller, C. F. (1979). Detail and background in audiovisual lessons and their effect on learners. *Educational Communication and Technology Journal, 27*, 31–38.

Bruner, J. S. (1966a). *Towards a theory of instruction.* Cambridge, MA: Harvard University Press.

Bruner, J. S. (1966b). Some elements of discovery. In L. S. Shulman & E. R. Keislar (Eds.), *Learning by discovery: A critical appraisal* (pp. 101–113). Chicago: Rand McNally.

Burke, R. L. (1982). *CAI sourcebook.* Englewood Cliffs, NJ: Prentice-Hall.

Chung, J., & Reigeluth, C. M. (1992). Instructional prescriptions for learner control. *Educational Technology, 32*(10), 14–20.

Dix, A. J., Finlay, J. E., Abowd, G. D., & Beale, R. (1998). *Human-computer interaction* (2nd ed.). London: Prentice Hall Europe.

Duffy, T. M., Palmer, J. E., & Mehlenbacher, B. (1992). *Online help: Design and evaluation.* Norwood, NJ: Ablex.

Durrett, H. J. (Ed.). (1987). *Color and the computer.* Orlando, FL: Academic Press.

Dwyer, F. M. (1978). *Strategies for improving visual learning.* State College, PA: Learning Services.

Dwyer, F. M., & Moore, D. M. (1992). Effect of color coding on visually and verbally oriented tests with students of different field dependence levels. *Journal of Educational Technology Systems, 20*(4), 311–320.

Fleming, M., & Levie, W. H. (1978). *Instructional message design: Principles from the behavioral sciences.* Englewood Cliffs, NJ: Educational Technology.

Fleming, M., & Levie, W. H. (1993). *Instructional message design: Principles from the behavioral and cognitive sciences* (2nd ed.). Englewood Cliffs, NJ: Educational Technology.

Gagné, R. M., Wager, W., & Rojas, A. (1981, September). Planning and authoring computer-assisted instruction lessons. *Educational Technology 21*(9), 17–21.

Giardina, M. (Ed.). (1991). *Interactive multimedia learning environments: Human factors and technical considerations on design issues.* Berlin: Springer-Verlag.

Goforth, D. (1994). Learner control = decision making + information: A model and meta-analysis. *Journal of Educational Computing Research, 11*(1), 1–26.

Grabinger, R. S. (1993). Computer screen designs: Viewer judgments. *Educational Technology Research and Development, 41*(2), 35–73.

Gropper, G. L. (1991). *Text displays: Analysis and systematic design.* Englewood Cliffs, NJ: Educational Technology.

Hannafin, M. J. (1984). Guidelines for using locus of instructional control in the design of computer-assisted instruction. *Journal of Instructional Development, 7*(3), 6–10.

Hannafin, M. J. (1987). The effects of orienting activities, cueing, and practice on learning of computer-based instruction. *Journal of Educational Research, 81*(1), 48–53.

Hannafin, M. J., & Hooper, S. (1989). An integrated framework for CBI screen design and layout. *Computers in Human Behavior, 5*(3), 155–165.

Hannafin, R. D., & Sullivan, H. J. (1995). Learner control in full and lean CAI programs. *Educational Technology Research and Development, 43*(1), 19–30.

Hartley, J. (1996). Text design. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 795–820). New York: Simon & Schuster Macmillan.

Hays, T. A. (1996). Spatial abilities and the effects of computer animation on short-term and long-term comprehension. *Journal of Educational Computing Research, 14*(2), 139–155.

Heines, J. M. (1984). *Screen design strategies for computer-assisted instruction.* Bedford, MA: Digital Press.

Heller, R. S., & Martin, C. D. (1999). Multimedia taxonomy for design and evaluation. In B. Furht (Ed.), *Handbook of multimedia computing* (pp. 3–16). Boca Raton, FL: CRC Press.

Hicken, S., Sullivan, H., & Klein, J. (1992). Learner control modes and incentive variations in computer-assisted instruction. *Educational Technology Research and Development, 40*(4), 15–26.

Jonassen, D. H. (1989). Functions, applications, and design guidelines for multiple window environments. *Computers in Human Behavior, 5*(3), 185–194.

Jonassen, D. H. (Ed.). (1982). *The technology of text (Volume 1): Principles for structuring, designing, and displaying text.* Englewood Cliffs, NJ: Educational Technology.

Jonassen, D. H. (Ed.). (1985). *The technology of text (Volume 2): Principles for structuring, designing, and displaying text.* Englewood Cliffs, NJ: Educational Technology.

Laurel, B. (Ed.). (1990). *The art of human–computer interface design.* Reading, MA: Addison Wesley.

Lawless, K. A., & Brown, S. W. (1997). Multimedia learning environments: Issues of learner control and navigation. *Instructional Science, 25*(2), 117–131.

Lee, S.-C. (1996). Perceptual considerations in icon design for instructional communication. *Educational Technology, 36*(2), 58–60.

Mann, B. (1995). Enhancing educational software with audio: Assigning structural and functional attributes from the SSF model. *British Journal of Educational Technology, 26*(1), 16–29.

Merrill, M. D. (1988). Don't bother me with instructional design—I'm busy programming!: Suggestions for more effective educational software. *Computers in Human Behavior, 4*(1), 37–52.

Merrill, M. D., Schneider, E. W., & Fletcher, K. A. (1980). *TICCIT.* Englewood Cliffs, NJ: Educational Technology.

Merrill, P. F., & Bunderson, C. V. (1981). Preliminary guidelines for employing graphics in instruction. *Journal of Instructional Development, 4*(4), 2–9.

Milheim, W. D., & Martin, B. L. (1991). Theoretical bases for the use of learner control: Three different perspectives. *Journal of Computer-Based Instruction, 18*(3), 99–105.

Misanchuk, E. R. (1992). *Preparing instructional text: Document design using desktop publishing.* Englewood Cliffs, NJ: Educational Technology.

Morrison, G. R., Ross, S. M., O'Dell, J. K., & Schultz, C. W. (1988). Adapting text presentations to media attributes: Getting more out of less in CBI. *Computers in Human Behavior, 4*(1), 65–75.

Norman, K. L. (1991). *The psychology of menu selection: Designing cognitive control at the human/computer interface.* Norwood, NJ: Ablex.

Paap, K. R., & Roske-Hofstrand, R. J. (1986). The optimal number of menu options per panel. *Human Factors, 28,* 377–385.

Park, I., & Hannafin, M. J. (1993). Empirically based guidelines for the design of interactive multimedia. *Educational Technology Research and Development, 41*(3), 63–85.

Pett, D., & Wilson, T. (1996). Color research and its application to the design of instructional materials. *Educational Technology Research and Development, 44*(3), 19–35.

Psotka, J., Kerst, S., Westerman, P., & Davison, S. A. (1994). Multimedia learner control and visual sensory-level supports for learning aircraft names and shapes. *Computers and Education, 23*(4), 285–294.

Reder, L. M., & Anderson, J. R. (1980). A comparison of texts and their summaries: Memorial consequences. *Journal of Verbal Learning and Verbal Behavior, 19,* 121–134.

Reeves, T. C. (1993). Pseudoscience in computer-based instruction: The case of learner control research. *Journal of Computer-Based Instruction, 20*(2), 39–46.

Relan, A. (1995). Promoting better choices: Effects of strategy training on achievement and choice behavior in learner-controlled CBI. *Journal of Educational Computing Research, 13*(2), 129–149.

Rieber, L. P. (1994). *Computers, graphics, & learning.* Madison, WI: W.C.B. Brown & Benchmark.

Rigney, J. W., & Lutz, K. A. (1976). Effects of graphic analogies of concepts in chemistry on learning and attitude. *Journal of Educational Psychology, 68,* 305–311.

Ross, S. M., Morrison, G. R., & Schultz, C. W. (1994). Preferences for different CBI text screen designs based on the density level and realism of the lesson content viewed. *Computers in Human Behavior, 10*(4), 593–603.

Schuerman, R. L., & Peck, K. L. (1991). Pull-down menus, menu design, and usage patterns in computer-assisted instruction. *Journal of Computer-Based Instruction, 18*(3), 93–98.

Shin, E. C., Schallert, D. L., & Savenye, W. C. (1994). Effects of learner control, advisement, and prior knowledge on young students' learning in a hypertext environment. *Educational Technology Research and Development, 42*(1), 33–46.

Shneiderman, B. (1998). *Designing the user interface: Strategies for effective human–computer interaction* (3rd ed.). Reading, MA: Addison-Wesley.

Silverstein, L. D. (1987). Human factors for color display systems: Concepts, methods, and research. In H. J. Durrett (Ed.), *Color and the computer* (pp. 27–61). Orlando, FL: Academic Press.

Smith, W. (1987). Ergonomic vision. In H. J. Durrett (Ed.), *Color and the computer* (pp. 101–113). Orlando, FL: Academic Press.

Steinberg, E. R. (1989). Cognition and learner control: A literature review, 1977–1988. *Journal of Computer-Based Instruction, 16*(4), 117–121.

Swan, K. (1996). Exploring the role of video in enhancing learning from hypermedia. *Journal of Educational Technology Systems, 25*(2), 179–188.

Szabo, M., & Poohkay, B. (1996). An experimental study of animation, mathematics achievement, and attitude toward computer-assisted instruction. *Journal of Research on Computing in Education, 28*(3), 390–402.

Tennyson, R. D. (1981). Use of adaptive information for advisement in learning concepts and rules using computer-assisted instruction. *American Educational Research Journal, 18,* 425–438.

Tufte, E. R. (1983). *The visual display of quantitative information.* Cheshire, CT: Graphics Press.

Tufte, E. R. (1990). *Envisioning information.* Cheshire, CT: Graphics Press.

Tufte, E. R. (1997). *Visual explanations: Images and quantities, evidence and narrative.* Cheshire, CT: Graphics Press.

Wager, W., & Gagné, R. M. (1988). Designing computer-aided instruction. In D. H. Jonassen (Ed.), *Instructional designs for microcomputer courseware* (pp. 35–60). Hillsdale, NJ: Lawrence Erlbaum.

Wileman, R. E. (1980). *Exercises in visual thinking.* New York: Hastings House.

Williams, M. D. (1996). Learner-control and instructional technologies. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 957–983). New York: Simon & Schuster Macmillan.

Williams, R. (1994). *The non-designer's design book.* Berkeley, CA: Peachpit Press.

SUMMARY OF GENERAL FEATURES

INTRODUCTION

Use a short title page.

Provide clear and concise directions.

Allow user identification.

LEARNER CONTROL

Use the mouse whenever possible.

Use the keyboard also for more expert users.

Use buttons for global controls and frequent actions.

Use menus for global controls.

Provide controls that are obvious and easy to use.

Use cursor changes, rollovers, and confirmation with controls.

Provide consistent position, appearance, and function in controls.

Design controls in accordance with your users and your content.

Make controls and directions for them visible only when available.

PRESENTATION OF INFORMATION

Be consistent.

Use presentation modes appropriately (e.g., text, sound, video).

Text should be lean, clear, well formatted, and at an appropriate reading level.

Use graphics and video for important information.

Video should be short and controllable.

Use speech to catch attention, give directions, and facilitate dual coding.

Use color consistently and sparingly.

Maintain good color contrasts, such as between foreground and background.

PROVIDING HELP

Procedural help should always be available.

Provide context-sensitive help.

Use rollovers as a form of constant help.

Always provide a help button when help is available.

Provide help in a manual for starting the program.

ENDING A PROGRAM

Distinguish temporary versus permanent termination.

Always allow temporary termination.

Provide safety nets when the learner requests termination.

Give credits and a final message at the end.