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An Investigation of Behaviorist and Cognitive Approaches to Instructional Multimedia Design

PATRICIA DEUBEL
Educational Consultant
Ohio, USA
deubelp@neo.rr.com

Typically, guidelines for design of interactive multimedia systems have been based on intuitive beliefs of designers rather than being founded on relevant research and theory. As advances in technology create new opportunities for education, it is important to use a range of theoretical perspectives to optimize use of new technology in teaching and learning. This article explores behaviorist and cognitive approaches to interactive multimedia instructional design (ID). Basic concepts, characteristics of ID, and comparisons between each are discussed. Interface design guidelines for learning with multimedia are presented, which link theory with practice in effective multimedia ID. Universal Design for Learning is described, which sheds light on future research in ID to accommodate the diversity of learners.

Major conclusions include that no one theoretical foundation exists for ID practice that is suitable for all applications. Dick and Carey's behaviorist model, Willis' constructivist model, Reigeluth's Elaboration Theory, Keller's ARCS model, Merrill's Instructional Transaction Theory, and Gagné's learning hierarchy illustrate the abundance of theoretical frameworks to assist designers in decision making. Theories continually evolve or are revised as a result of research or critique by designers or theorists in the field. In the long term a blending of behaviorist and cognitive approaches seems inevitable.

Behaviorism and cognitivism are the two dominant theoretical positions in the field of learning with interactive courseware (Jonassen, 1991; Atkins, 1993; Hannafin, Hannafin, Hooper, Rieber, & Kini, 1996). Developments in design of such materials appear to have followed shifts in the dominant paradigms within psychology. Early computer-based materials are seen to be influenced by behaviorist concepts while discovery learning materials are felt to be founded on later cognitive models of information processing and constructivism. The increase in cognitive approaches in the 1980s may be due as much to technology developments in object-oriented programming, hypermedia, and interactive video as to the rise within psychology of cognitive theorists (Atkins, 1993).

Designers are adopting a mixed approach to design because it offers complete flexibility (Atkins, 1993). For example, some business and industry designers reveal a blending of analysis and evaluation of the objectivist approach with simulations and individualized progress of constructivist approaches (Dick, 1996). Typically, however, guidelines for design of interactive multimedia systems have been based on intuitive beliefs of designers rather than being founded on relevant psychological, pedagogical, and technological research and theory (Hannafin & Hooper, 1989; Park & Hannafin, 1993; Spiro, Feltovich, Jacobson, & Coulson, 1991).

Intuition and creativity have played major roles in the development and implementation of constructivist learning environments (Dick, 1997) for a reason. Until the appearance of the Recursive and Reflective, Design and Development (R2D2) model by Willis (1995), there had been almost no articles detailing explicit alternatives to the Dick and Carey objectivist model to help designers create instructional materials based on constructivist theory. The Dick and Carey model, which is in its fifth edition (Dick, Carey, & Carey, 2001), has been the leading behavioral instructional systems design model (Willis, 1995; Willis & Wright, 2000) since it became public in 1968.

Park and Hannafin (1993) indicated that the psychological foundation, in general, focuses on how learners think, learn, and process information and is largely media-independent. This foundation is based on research and theory on meaningful learning, schema theory, prior knowledge, hierarchical cognitive structure, elaboration, depth of processing, generative learning, situated learning, conceptual models and metaphors, and dual coding theory. The pedagogical foundation is based on research, theories of instruction, and teaching strategies, which include Gagné's work in learning hierarchies, elaboration theory, structural cueing, use of advance organizers, and anchored instruction. The technological foundation addresses the potential of technology to redefine teaching and learning, the capabilities of specific multimedia technologies, and the capabilities and limitations of interactive multimedia technology.

As advances in technology offer new opportunities for learning, it is important to use a range of theoretical perspectives to optimize use of new technologies in teaching and learning (Wild & Quinn, 1998). This article explores behaviorist and cognitive approaches to interactive multimedia instructional design (ID) and delves into the foundations noted by Park and Hannafin (1993). Basic concepts of each approach, characteristics of ID, and similarities and differences between each will be discussed. Interface design guidelines for learning with multimedia will be presented, which link theory with practice in effective multimedia ID. Universal Design for Learning (UDL) is described, which sheds light on future research in ID to accommodate the diversity of learners.

BEHAVIORIST CONCEPTS

The legacy of educational technology has been behaviorism (Winn & Snyder, 1996), the roots of which lie in studies of observable behavior that were prevalent in the early 20[th] century (Atkins, 1993). Although instructional systems technology began rejecting many behaviorist assumptions in the 1980s in favor of the cognitivist view (Jonassen, 1991), the theory is the basis for innovations such as computer assisted instruction, mastery learning, minimal competency testing, educational accountability, situated cognition, and even social constructivism. The primary tenet of behaviorism is that there is a predictable and reliable link between a stimulus and the response it produces. If behavior is predictable, designers need to identify subskills students must master that lead to a learned behavior, and then select stimuli and presentation strategies that build the subskills. Designers assume that an instructional strategy that has had a certain effect in the past will do so again (Burton, Moore, & Magliano, 1996).

A major assumption is that learners are not just passive entities who react to environmental stimuli. Learners learn by doing, experiencing, and engaging in trial and error. What has been learned, under what conditions, and the consequences that support or maintain the learned behavior all work together, and must be observable and measurable. A second assumption of behaviorism is that learning is a change in behavior due to experience and a function of building associations between the occasion on which the behavior occurs (stimulus event) and the behavior itself (response event). Repeated continuous pairing of the stimulus with the response strengthens learning. To change behavior in an educational setting, learners must be assessed for their needs and capabilities so that instruction is appropriate and meaningful. Observable goals can then be written. Learning tasks are ordered logically according to a hierarchy. Learners' performance of tasks is measured against objective criteria for mastery and correctness. Reinforcement, which is contingent on successful achievement at each stage, maintains previously learned behaviors (Burton et al., 1996).

Atkins (1993) noted behaviorist ID characteristics with respect to subject matter, sequencing, learner control, and learning. Those are described in the following sections.

Subject Matter

Material is broken down into small, logically discrete instructional steps and is often presented as a rule, category, principle, formula, or definition. Positive examples are given to reinforce understanding, followed by negative examples to establish conceptual boundaries.

Sequencing and Learner Control

Designers write sequences of prespecified formal instructions with conditional or unconditional branching to later/earlier parts of the program and specify branching choices at predetermined points in the program. Activities are sequenced for increasing difficulty or complexity. The sequence and pacing through the material is usually without learner control. To maximize learning efficiency, learners may be routed to miss or repeat certain sections of material based on performance on a diagnostic test, or on tests within the sequence of learning activities. The amount of practice or revision they require may also vary based on performance.

Learning

The required operation, procedure, or skill is demonstrated and broken down into its parts with appropriate explanation before learners are expected to copy the desired behavior. Performance standards are made explicit. Learners build proficiency from frequent review or revision with check tests at strategic points or repeat practice with feedback. Design emphasizes low error rate and use of remedial loops back through material, if learner test performance seems to warrant it. Extrinsic or intrinsic reinforcement messages are used to maintain motivation.

Atkins (1993) concluded that a structured, deductive approach to design multimedia applications can lead to rapid acquisition of basic concepts, skills, and factual information within a clear framework. The effectiveness of behavioral design approaches for higher-order learning tasks or for transfer of learning is yet unproven, however.

COGNITIVE CONCEPTS

Theories on how people learn include cognitive, social psychological, and interactionist or experimental perspectives (Wild & Quinn, 1998). The diversity is often grouped into two trends: the individual cognitive and the sociocultural. The individual cognitive trend, derived from Piaget's theory, emphasizes the constructivist activity of individuals as they try to make sense of the world. The sociocultural trend emphasizes the socially and culturally situated context of cognition as expressed by Vygotsky (Duffy & Cunningham, 1996). "Concepts in cognitive psychology became meaningful when the metaphor of the central processing unit of the computer could be used to describe the functioning of the brain" (Dick, 1997, p. 48).

Principles of behaviorism omit the psychology of unobservable mental states or Gestalts and the subjectivity of introspection, both of which are a part of human behavior. Cognitive psychologists believe prior knowledge and mental processes intervene between a stimulus and response that operate to reduce the predictability of human behavior (response) given a stimulus. Mechanisms, such as chunking or grouping like items and interactive mental imagery, intervene between a stimulus and response to promote memory (Winn & Snyder, 1996).

Unlike behavioral psychology, cognitive psychology is concerned with meaning or semantics (Winn & Snyder, 1996). According to Wittrock's generative learning model, people learn meaningful material by generating relationships among new information and knowledge already stored in long-term memory. Three kinds of learning are defined in Rumelhart and Norman's schema-based theory of long-term memory. Accretion, associated *with memorization, involves acquisition of factual information. Schema cre*ation occurs as a result of encountering examples, analogies, metaphors, and tutorial interactions. Tuning or schema evolution involves gradual refinement of existing schema as a result of task practice or concept use (Shuell, 1986). Cognitive oriented instructional strategies are chosen for the likelihood of modifying schemata rather than of modifying behavior (Winn & Snyder, 1996).

Mayer (1997) proposed a generative theory of multimedia learning based on Wittrock's generative theory and Paivio's (Clark & Paivio, 1991) dual coding theory. Paivio's theory proposes two separate, though connected, memory systems in which people can encode information as language-like propositions or picturelike mental images. In multimedia environments, learners construct meaningful knowledge by "selecting words and selecting images from the presented material, organizing words and organizing images into coherent mental representations, and integrating the resulting verbal and visual representations with one another" (Mayer, 1997, p. 4).

The key to successful learning using the cognitive model is the quality of processing that occurs while actively engaging with subject matter (Atkins, 1993; Duffy & Cunningham, 1996). For example, Brown, Collins, and Duguid (1989) proposed cognitive apprenticeship as a means of active engagement, which embeds learning in authentic activities and social interactions. Quality of processing might be affected by the degree in which strategies such as discovery learning, scaffolding, instructor as coach, problem based instruction/learning, learner control, assessment in context of learning, and cooperative learning are applied in ID. Duffy and Cunningham (1996) explained those concepts.

Discovery Learning

The goal of discovery learning is learning to learn, including the ability to question, evaluate one's strategies, and answer questions in the content domain. Discovery learning is not necessary to learn definitions, procedures, and outcomes from an existing body of knowledge.

Scaffolding

Scaffolding, based on Vygotsky's definition of zone of proximal development, is the gradual removal of a tutor's support for the individual to become an independent problem solver as the individual appropriates knowledge and brings it under his/her own conscious control.

Instructor as Coach

The instructor-coach may be more knowledgeable and as mentor seek to expand a learner's current conceptions. Each seeks to understand the other's views. In the end, the learner may not mimic the coach, but the learner can defend and the coach can respect the other view.

Problem-Based Instruction/Learning

Learning is organized around problem solving, rather than around subject matter. The teacher's role is to support students in their critical thinking skills, self-directed learning skills, and content knowledge in relation to problems. The teacher does not teach students what they should know or set a time for when they should know it.

Learner Control

Giving learners control over pacing, sequence, and actual content of information presented is based on assumptions that learners know what is best for them and are capable of acting appropriately on that knowledge. If learners do not meet either assumption, then the computer or teacher is given control of content and learner tasks.

Assessment in Context of Learning

In traditional settings, assessment is done after learning occurs. In a constructivist framework, assessment is embedded within an activity and must be in a context of problem solving. The distinction between learning and testing becomes blurred.

Cooperative Learning

Groups work together to solve problems. The goal is to share, challenge, and form alternative viewpoints. Herrington and Standen (2000) proposed a constructivist shell to guide the design and development of an interactive multimedia program. Criteria include use of authentic contexts and *authentic activities, access to expert performances and modeling of processes*, multiple roles and perspectives, collaborative events, opportunities for articulation and reflection, coaching and scaffolding, and authentic assessment. Cognitive (information-processing or constructivist) ID characteristics that fit this model include orientation activities, advance organizers, metacognitive devices, and active engagement, which Atkins (1993) described as follows.

Orientation Activities

Orienting activities prior to a learning task help learners to focus on new information, cut down the time needed to process information, and improve learning efficiency. Text, aural, or visual cueing aim to hold new information longer in short-term memory for active engagement.

Advance Organizers

Advance organizers or anchoring concepts are introduced at the start of material to help learners make sense of information that follows. According to Ausubel (1960), however, the pedagogic value of advance organizers depends in part upon how well material is organized. Advance organizers probably facilitate incorporation and longevity of verbal material in two ways. First, they activate whatever relevant concepts are already established in the learner's cognitive structure to increase the task's familiarity and meaningfulness. Second, appropriate advance organizers provide optimal anchorage, which promotes initial incorporation of new material and its later resistance to obliteration. If appropriately relevant concepts are not present, learners use whatever concepts are available.

Metacognitive Devices

Metacognitive devices such as advice statements, help facilities, suggestions for more effective engagement and processing of information are employed. Providing a metacognitive framework is not easy, however. Much depends on the ability of learners to use such features.

Active Engagement

Learners are expected to analyze, synthesize, summarize, describe, and solve problems. They are expected to build hypotheses, explanations, definitions, categories, rules, and so on, through study of examples and reflection on their own experiences. To help them, instruction uses frequent decision points and direct involvement in games, microworlds, and simulations with results of decisions seen immediately. A variety of information sources are available to learners, who are moved back and forth between symbolic representations of phenomena and the real-life referent. Students also interact with experts (Atkins, 1993).

According to Winn and Snyder (1996), decisions regarding learning strategies should occur during instruction, not ahead of time. Learning and ID are best achieved by developing learning environments whose function is not entirely prescribed, but which can adapt in real time to student needs. The latest interactive multimedia systems and virtual reality environments allow students freedom to learn in their own way, rather than in the way a designer prescribes. Rodriques (2000) cautioned, however, that making software nonlinear by building in hyperlinks for learner control does not make software constructivist, though it may make it less behaviorist. Users can still navigate without reflective thought.

The problem in determining the effectiveness of cognitive design characteristics lies in the difficulty of knowing what is going on in the mind of learners. Evaluators are, therefore, forced back on measures such as apparent time on task, apparent engagement with the task presented, and subject estimations of its effectiveness (Atkins, 1993).

COMPARISON OF BEHAVIORIST AND COGNITIVE ID PERSPECTIVES

Atkins (1993), Burton et al., (1996), Hannafin et al. (1996), Jonassen (1991) and Willis (1995) compared behaviorist and cognitive perspectives with respect to mental activity, structuring, tutoring and assessment, motivation, program versus learner control and procedural ID models. Hannafin, Hill, and Land (1997), Litchfield (1993), Milheim and Martin (1991), and Orr, Golas, and Yao (1994) have addressed difficulties and solutions associated with providing learner control.

Mental Activity

The view of mental activities as actions, as opposed to their being considered indications of the presence of a consciousness or mind as a separate entity, are central differences between behavioral and cognitive orientations. Cognitive psychology is associated with mind; behaviorism is associated with body. Cognitive notions include schema, knowledge structures, and duplex memory, for example, and are structured ways to investigate consciousness. There are no behavioral equivalents. Differences are reflected in ID (Burton et al., 1996).

Structuring

From the behaviorist perspective, instruction is made explicit with tasks and subtasks broken up into lessons and modules. From the cognitive perspective, structuring means supplying a framework around a task in which learners develop and test their own understanding. Learners may have to find relevant information for themselves from sources provided. This complexity requires more reflective thought (Atkins, 1993). Behaviorists would identify explicit learning objectives; cognitivists would use advance organizers. Explicitly stated objectives may limit students' ability to use information in situations that are not similar to those in which initial learning occurred. Advance organizers stimulate higher-level learning (Hannafin et al., 1996).

Tutoring and Assessment

For behaviorists, tutoring is focused on testing, analyzing performance, and providing remediation or extension of instruction. Assessment or tests of some kind (e.g., multiple-choice tests or solving problems with right answers) seek to measure performance in a quantifiable way on decontextualized packets of learning. For cognitivists, tutoring involves coaching and scaffolding at appropriate times. Assessment becomes integrated, authentic, and inseparable from activities themselves (Atkins, 1993).

Motivation

Behaviorists value success as motivating and place more importance on extrinsic rewards, goal setting, and goal achievement, rather than on intrinsic rewards. Cognitivists emphasize the motivating affect of learners as problem solvers or information seekers. Emphasis is on intrinsic feelings of success perceived by learners who view their learning as individually worthwhile in return for their effort (Atkins, 1993).

Program versus Learner Control

Unlike a behaviorist approach, the cognitive approach suggests learners should be given control. Few students, however, are able to optimize their learning by setting meaningful goals, identifying appropriate resources, evaluating relevance, and monitoring their comprehension. They require support (Hannafin, Hill, & Land, 1997). Prescriptive models do little to develop learners who can make their own instructional decisions. Adaptive instruction, based on user traits and ongoing performance, is an alternative to complete program control or unassisted learner control. Advisement may assist them to explore the learning environment, particularly hypermedia environments. Advisement augments metacognitive processing, may be useful for reluctant or passive learners (Hannafin et al., 1996), and produces the best results for most students. Several search options should be included because learners differ in how they retrieve information, and have various learning styles and prior knowledge (Litchfield, 1993).

Learner control might be effective when students may complete sequences in any order, when students are familiar with a topic and can make appropriate sequence choices, or when training is for cognitive strategies or higher order problem-solving tasks. It might be effective when students have significant previous content knowledge, high ability, or high motivation, *when there is high probability that students will succeed in learning content* regardless of content chosen, or when skills are not critical and training is optional. Learner control is not effective in situations where material has a prerequisite order or when all topics are required for successful program completion (Milheim & Martin, 1991; Orr, Golas, & Yao, 1994). Learner control of pacing might be effective when students believe their chances of success increase, if they spend more time and effort, or when they have not achieved required objectives and feedback suggests spending more time for mastery (Milheim & Martin, 1991).

Similarities

In spite of differences, behavioral and cognitive approaches are being used in the same multimedia application. Both involve analysis, decomposition, and simplification of tasks to make instruction easier and more efficient (Jonassen, 1991). Both use devices to arouse, attract, and focus attention. Both force learner engagement through interactive decision-making points in the material. Both give importance to intrinsic feedback, though it may be expressed in voluntary *help* or *advice* options in applications with cognitive design. Both value meaningful learning and realistic contexts for application of knowledge and skills (Atkins, 1993).

Procedural ID Models

Willis (1995) compared family characteristics of behaviorist or objective-rational ID models to constructivist-interpretivist ID models. Behaviorist models feature a sequential and linear process, and top down and systematic planning. Objectives guide development. Experts, who have special knowledge, are critical to ID work. Careful sequencing and teaching of subskills is important. The goal is delivery of preselected knowledge using direct instruction methods (e.g., drill and practice, tutorials, use of computer as information deliverer, evaluator, and recordkeeper). Summative evaluation is valued because it will determine whether the material works. Collection and analysis of objective data from identifying entry behaviors to task and concept analysis, pretests, embedded tests, and posttests are also critical.

In contrast, Willis (1995) indicated that the ID process in constructivist models is recursive, nonlinear, and sometimes chaotic. Planning is organic developmental, reflective, and collaborative. Objectives emerge from design and development work. General ID experts do not exist. Instruction emphasizes learning in meaningful contexts (e.g., anchored instruction, situated cognition, cognitive apprenticeships, cognitive flexibility hypertext, problem solving, and use of hypermedia/multimedia navigable resources). The goal is personal understanding. Formative evaluation, not summative, is critical to improve the product. Subjective data from sources such as interviews, observations, user logs, and expert/user critiques may be the most valuable.

Although the Dick and Carey model exemplifies behaviorist ID models, the accountability movement and total quality management influenced changes that first appeared in the fourth edition that might appeal to constructivists. A major change emphasizes analyzing learners and contexts in which learning occurs, instead of experts identifying entry behaviors and characteristics. The first step now states that a needs assessment should be used to determine instructional goals. The process includes planning for the transfer of learning to the performance environment. As in prior versions, performance objectives and criterion-referenced test items are developed, and formative and summative evaluations are conducted to improve the product (Dick, 1996).

The R2D2 model exemplifies constructivist ID models and features three flexible guidelines: recursion (iteration), reflection, and participation.

Procedures can be completed in any order. Objectives, content, teaching and learning activities, and more, gradually emerge rather than being specified early in the ID process (Willis, 1995, 2000). Major focal points include Define Focus, Design and Develop, and Disseminate. Define Focus involves creating a participatory team that includes users as active members, progressive problem solution, and developing contextual understanding. Design and Development involves selecting a development environment including the tools and design process, cooperative inquiry, which is constructivist terminology reflecting traditional formative evaluation, and product design and development. Final packaging, diffusion, and adoption complete the Dissemination Focus. Summative evaluation is non-traditional. It only indicates what happens when the material is used in a particular context and way with a particular group of learners (Willis & Wright, 2000).

RULES FOR INTERFACE DESIGN FOR EFFECTIVE LEARNING WITH MULTIMEDIA

Ultimately theories and learning principles must be practically implemented. Information processing theory, learning hierarchy theory, and elaboration theory are considered appropriate for computer-assisted instruction (CAI) design, with the latter theory of particular relevance for designing hypermedia environments. The theories provide strategies to help designers organize instruction and show interrelationships among subject matter content (Hoffman, 1997). Using constructivist philosophy to ground multimedia design is problematic, however, because of differences in interpretation and shared understanding of terms between an education researcher and designer, and technology limitations. The challenge lies in communicating and discussing such issues as technology features, contemporary views of learning, intended outcomes of material being developed, and the culture in which the material will be used (Rodriques, 2000).

The user interface plays a central role in learning using multimedia. A quality interface can enhance the learning experience, increase the amount of knowledge retained (Vilamil-Casanova & Molina, 1996), and serves as a cognitive dashboard from which users control the program and monitor their progress (Jones, Farquhar, & Surry, 1995). Vilamil-Casanova and Molina (1996) provided eight rules for interface design, which also support guidelines that are effective for poor readers (Kenworthy, 1993):

1. Keep cognitive load low.
2. Avoid dividing attention.
3. Use media to direct attention.
4. Keep important information visible.
5. Encourage rehearsal.
6. Use concrete words and multiple media.
7. Design effective exercises.
8. Create realistic simulations.

Keller's attention, relevance, confidence, and satisfaction model (ARCS) features enhancing and sustaining motivation strategies, which instructional designers can build into the interface. For example, use of a menu-driven program structure to enable learners to control access to different parts of courseware enhances learners' confidence (Keller & Song, 2001). The following sections explore those rules and strategies.

Keep Cognitive Load Low

The amount of screen information presented depends on the age and grade level of learners. Text and visuals should complement each other, offering different yet related information to promote learning (McFarland, 1995). Layer information to accommodate multiple levels of complexity and to accommodate differences in related prior knowledge (Park & Hannafin, 1993). Layering information with pop-up menus, buttons, or hot text allows users to move through a program in a non-threatening manner. As they need more information, they can move deeper through the layers (Jones et al., 1995). This structure is also in keeping with Reigeluth's Elaboration Theory, which emphasizes a tiered design with the most fundamental and representative ideas at the top and elaboration levels below (Hoffman, 1997; English & Reigeluth, 1996).

Avoid Dividing Attention

Because individuals have different learning styles, screen design should present the same message or information with a combination of sound, text, graphics, and other resources. This also enhances information retention (Vilamil-Casanova & Molina, 1996). However, Mayer and Moreno (1998) pointed out that in split-attention situations in which words and pictures are both presented visually, learners are able to select fewer pieces of relevant information because visual working-memory is overloaded. Results of their split-attention effect study indicated that students learned better when pictorial information was accompanied by verbal information presented in an auditory (different modality presentation) rather than a visual modality (same modality presentation). The most important practical implication of the study is that auditory narration rather than onscreen text should accompany animations.

Designers should provide methods that help learners acquire knowledge from multiple perspectives and cross-reference knowledge in multiple ways (Park & Hannafin, 1993), which is in keeping with Cognitive Flexibility Theory (Spiro et al., 1991). Spiro et al. were concerned with learners' ability to transfer knowledge and skills to new problem solving situations. For this reason, they emphasized presenting information from multiple perspectives and using many case studies with diverse examples. Hypertext environments are good candidates for promoting cognitive flexibility.

Tergan (1997), however, might urge designers to exercise this implication with caution. With multiple representations, there is high probability that at least one representation will be misunderstood, which could hamper an overall understanding of the material, particularly for novice students. This conclusion is in line with the assumption of Cognitive Flexibility Theory, which holds that only advanced learners with high level domain knowledge and metacognitive competence may profit from multiple representations of information.

Recent developments, however, on Universal Design for Learning (UDL) at the Center for Applied Special Technology (Pisha & Coyne, 2001) indicated that, at a minimum, UDL must provide multiple representations. Text alone is insufficient to satisfy the needs of the broadest range of students, including those with disabilities. For example, Scholastic's program, Read 180, uses video to help scaffold students with background knowledge. They hear the words and know their context before reading a passage (Kurkjian, 1999).

Use Media to Direct Attention

Colors, arrows, and animation can be used to direction attention. The background, icons, and navigation tools should be consistent with the application's theme (Vilamil-Casanova & Molina, 1996). The metaphor should be obvious to users and should reflect the program's content (Jones et al., 1995). Provide tactical, instructional, and procedural assistance because individuals vary widely in their need for guidance (Park & Hannafin, 1993).

Kenworthy (1993) suggested avoiding navigational routing terms such as *return, exit, load, enter,* or *cancel.* For example, if designers use the term *return*, poor readers may not know where they have come from in the program. Graphic icons or still photos can be used to illustrate menu choices.

Color should enhance communication. Pastels and soft grays provide a nonintrusive background that leads to less fatigue than highly saturated colors (McFarland, 1995). Stemler (1997) suggested using a maximum of three to six colors per screen. Use bright colors for the important information and dark text color on neutral backgrounds. Avoid hot colors and color schemes such as blue/orange, red/green, and violet/yellow. Use commonly accepted colors for certain actions, as red for stop or yellow for caution. According to Hannafin et al. (1996), however, research has not supported the role of color as a primary instructional variable. Color is most effective for organizing information and for providing contrast between screen objects.

Keep Important Information Visible

A user interface should contain access to support information like help screens (e.g., tutorials, instructions, and dictionaries). Icon placement should be consistent so that users do not have to guess what to do next or use the mouse to point and click hoping to find a way to continue (Vilamil-Casanova & Molina, 1996). Provide concept maps to visually improve learners' awareness of interrelationships among concepts, and hypermaps to indicate a learner's location relative to other lesson segments (Park & Hannafin, 1993). Text-based indexes, outlines, and tables of content might be considered as alternatives to maps because using hierarchical diagrams of content, or iconographic maps of content may be too difficult to include and too confusing for users to understand (Jones et al., 1995).

Encourage Rehearsal

Place practice exercises after presenting a subject to reinforce learning by transferring information from working memory to long-term memory. Rehearsal can be accomplished by using simple rote repetition where text is accompanied by a voice-over repeating text to be learned, or by enabling learners to enter alphanumeric responses to exercises in which they apply knowledge in an appropriate context (Vilamil-Casanova & Molina, 1996).

Reigeluth provided an ID methodology for organization and simple to complex holistic sequencing of subject matter in which rehearsal plays a key role. Application of his Elaboration Theory (ET), which is still undergoing growth and development, is particularly suited for learning in the cognitive and psychomotor domains (English & Reigeluth, 1996).

ET consists of a tiered design of epitomes and elaboration levels. The first lesson in a sequence, called the epitome, usually has from three to nine topics and includes a definition of a concept, examples, and practice applying the concept to new situations (Hoffman, 1997). An epitome might be improved, if designers indicate that it is entry-level and knowledge at that level is not sufficient for solving problems at more complex levels. They might assign an appropriate label to the epitome material (English & Reigeluth, 1996). Elaborations are primarily conceptual, procedural, or theoretical (Hoffman, 1997) and can be elaborated simultaneously, a process called multiple-strand sequencing (English & Reigeluth, 1996).

In addition to selecting and sequencing content (including prerequisite sequences), designers would summarize preview and review materials, synthesize to show interrelationships among related ideas, use analogies, embed cognitive strategy activators (e.g., pictures, mnemonics, or directions to learners to do something to remember information), and provide learner *control. Design using ET results in multiple, interrelated content modules* (Hoffman, 1997), each of which has provided for rehearsal.

Use Concrete Words and Multiple Media

According to dual coding theory, abstracts are difficult to remember and associate with familiar ideas or concepts (Clark & Paivio, 1991). Orally presented lessons that contain concrete information and evoking images are easier to comprehend and remember than lessons that do not contain these elements (Vilamil-Casanova & Molina, 1996).

Kenworthy (1993) noted that poor readers benefit from multiple media because they often get their information from television, so the mix of video, audio, and high quality graphics afforded by multimedia may grab their attention in ways that traditional approaches to instruction would not. Audio can explain menu choices, which can be highlighted as explained. Audio can be interrupted when learners are ready to make a selection. Audio that supports text should match the text exactly so that learners can identify unfamiliar words. Learners should be able to pause or repeat audio, as well as repeat text passages. Audio could be under learner control to toggle it on/off.

Orr et al. (1994), recommended audio use for short messages that require immediate student response. Audio should not interfere with reading from the text or compete with video presentations. Limit audio to what is relevant. Break long audio presentations into chunks separated by instructional activities. When possible, provide a corresponding visual for every piece of narration. Alternate male and female voices for variety and to maintain attention.

Video can link conceptual learning to real-life experiences and facilitates transfer of learning, as exemplified by the videodisc anchored instruction research by the Cognition and Technology Group at Vanderbilt (CTGV). The CTGV has demonstrated that anchored instruction makes Brown, Collins, and Duguid's (1989) idea of cognitive apprenticeship feasible (CTGV, 1993). Video provides an environment in which applications of principles, rules, definitions, and so on can be observed and analyzed. The database capacity of visual as well as computer components ensures that sufficient examples will be available for an inductive approach to learning to work effectively (Atkins, 1993). Use graphics and animation when video may overburden with too much detail or when users must focus on specific details (Orr et al., 1994; Thibodeau, 1997).

Design Effective Exercises

Exercises that incorporate text, sound, and graphics associated with a concept help to reinforce learning (Vilamil-Casanova & Molina, 1996). Keller and Song (2001) pointed out, however, that as novelty of working with multimedia features wears off, it becomes a challenge to stimulate and sustain students' motivation during CAI. They demonstrated that it is possible to design CAI to be motivationally adaptive to changes in learner motivation that might occur over time, and provided attention, relevance, and confidence strategies from Keller's ARCS motivation model that are useful for instructional designers.

Among attention sustaining strategies are keeping instructional segments relatively short, making effective use of screen display for ease of reading, intermingling information presentation screens with interactive screens, using a consistent screen format but with occasional variation, and avoiding dysfunctional attention-getting affects such as flashing words that might distract students' concentration. Underlines, italics, and bigger font sizes can be used to call attention to headings or key words (Keller & Song, 2001).

Attention strategies to enhance motivation include using question-response-feedback interactions that require active thinking. Present problem-solving situations in a context of exploration and partial revelation of knowledge. Clearly state objectives in terms of a lesson's importance and use examples from content areas and situations familiar to learners to enhance relevancy. Relevance might be sustained by using personal pronouns and the learner's name when appropriate and by using graphical illustrations to embed abstract or unfamiliar concepts in a familiar setting. Sustain learners' confidence by allowing them to return to the menu at any time and to control pacing from one screen to the next by hitting a key (Keller & Song, 2001).

Metacognitive demands are greater for loosely structured learning environments than for highly structured ones; therefore, provide prompts and self-check activities to aid learners in monitoring comprehension and adapting individual learning strategies (Park & Hannafin, 1993). Guidance can be offered using real characters with whom learners can positively identify (Atkins, 1993). Learners' confidence can be enhanced, if instructional designers include evaluation criteria, and mention prerequisite knowledge, skills, or attitudes that will help learners to succeed. Tell learners the number of test or drill items and whether the activity is timed. Further enhance confidence with appropriate words of praise to help attribute success to learners' ability and effort, and provide a summary to help monitor comprehension (Keller & Song, 2001).

Create Realistic Simulations

Activities, such as simulations, have the potential to promote reflection (Wild & Quinn, 1998). If users engage in a simulation one-on-one, fear of making mistakes and having others know about them is eliminated because only the computer knows how the simulation is going (Vilamil-Casanova & Molina, 1996). The R2D2 constructivist design process in which design and development are integrated seems to favor simulations as the fundamental instructional strategy (Dick, 1996). Authoring tools such as *Director*, *Authorware*, *SuperCard*, and *ToolBook* are change-friendly (Willis & Wright, 2000) and their use supports the R2D2 recursion principle.

It is possible to create realistic simulations and adaptive instruction, if designers use the knowledge object architecture that Merrill proposed in his Instructional Transaction Theory, which is an extension of his Component

Display Theory and Gagné's Conditions of Learning. This is an algorithm-based approach to ID, as opposed to a frame-based approach for branching programmed instruction typical of most current authoring systems. Subject matter is treated as data and thus, it can be uncoupled from the instructional strategy used to present subject matter. The benefit of the approach is that the same subject matter can be used with a number of different strategies based on the decisions made by learners as they interact with the computer program (Merrill & ID_2 Research Group, 1996; Merrill, 1999).

THE INTERFACE AND GAGNÉ'S FRAMEWORK FOR ID

According to Gagné, Briggs, and Wager (1992), cognitive strategies such as rehearsal strategies, elaboration strategies, and comprehension monitoring strategies can be built into the interface. Gagné's nine events of learning serve well as the framework for ID (Stemler, 1997), particularly for instructional multimedia (Wild & Quinn, 1998). His events of instruction have served as the predominant micro theory (what is done and how) within the Dick and Carey macro systems design theory (Dick, 1997). Each externally observable event of instruction is associated with a corresponding internal process (Gagné et al., 1992) as follows:

External:	**Internal:**
1. Gain attention.	Reception
2. Tell learners the objective.	Expectancy
3. Stimulate recall of prior learning.	Retrieval to working memory
4. Present stimulus with distinctive features, that is, tell or show the students what they are to do.	Selective perception
5. Provide learning guidance.	Semantic encoding
6. Elicit performance.	Learner responds
7. Provide feedback.	Reinforcement
8. Assess performance.	Retrieval and reinforcement
9. Enhance retention and transfer of learning.	Retrieval and spaced review

Screen design serves the role of *gaining attention* in Gagné's events of instruction and its organization of presentation stimuli influences how students process information. Szabo and Kanuka (1999) found that poor use of screen design principles of balance, unity, and focus was related to increased instructional time and reduced persistence in completing a lesson.

Screen design is improved by chunking information (Stemler, 1997) into manageable segments, which is a metacognitive feature that helps to minimize learners' feelings of being overwhelmed by content (Jones et al., 1995). For consistency among screens, provide key information in prominent locations with critical information at the beginning of a message. Place questions and important messages in the middle of the screen. Limit the number of lines per screen and use no more than two or three font types and sizes. Use highlighting to focus attention. Left justify text, and mix upper and lower case letters for faster reading (Stemler, 1997). People read text about 28% slower and with lower comprehension from a computer screen than from print-based media (Orr et al., 1994; Thibodeau, 1997).

Learners can be assisted with *objectives*, if the interface supports alternative paths to engage with material. Linkages need to reflect the diverse ways in which the system will be used (Park & Hannafin, 1993). Fixed paths through a multimedia learning experience might be used, each corresponding to and supporting different learning styles. As an alternative, using multiple paths of navigation would support a learner's choice to engage in information resources, sample problems, or practice opportunities (Wild & Quinn, 1998).

Because learners can become disoriented when using multimedia modules, provide clearly defined procedures for navigating within the system and accessing online support (Park & Hannafin, 1993). To *provide learner guidance*, the interface might include orientation cues to assist in navigation. Consistently placed navigational elements add structure to a program making it easier to use, provide learners with some control over events, and help build confidence in learners. Prompts and/or a navigation control bar are often located at the bottom of a screen. Elements include icons to quit the program, to access the next or previous screen, to obtain help or use a glossary, or to return to the main menu. Universal icons that are familiar to learners should be used (Stemler, 1997). Each icon should be clearly distinguishable from the next. Visuals and icons should be culturally sensitive (McFarland, 1995).

Multimedia use in an interface enables interaction, which is an integrated form of Gagné's events of instruction, *eliciting* and *assessing performance* (Stemler, 1997). Users must be able to control course presentation, access the elaboration of unknown terms, initiate animations, manipulate objects such as windows, navigate to test items, make responses to questions, be able to ascertain where they are in the program, and know how well they are progressing. All of these activities associated with computer based instruction contribute to the interaction mode of the program (Jones et al., 1995).

Orr et al. (1994) and Thibodeau (1997) suggested providing interactivity every two or three screens or every minute or two. Alternate and randomly move from content to practice to summary. Ask questions after, but not immediately following, content just presented. A gap between a question and its related content might force learners to mentally search for and review information, a process that enhances retention. Base questions on previously acquired knowledge and make sure they are designed to use information, not repeat memorized facts.

According to Rodriques (2000), at present most questions in software are written in multiple-choice form or require one-word answers. Questions ask what, rather than why or how, which is a fundamental difference between behaviorist and constructivist approaches to learning. The computer's capability to interpret natural language responses is not widely available. The state of artificial intelligence limits options available to designers. Consequently, the role of language, which is a crucial tenet of constructivism, is not easily accommodated in assessment with multimedia learning packages.

Provide feedback in the interface by using occasional motivational messages, as well as information about the correctness and/or appropriateness of the response. Feedback can be used to reinforce, elaborate, clarify (Stemler, 1997), present consequences of responses, demonstrate impact in context, note performance to date, diagnose, and prescribe (Hannafin et al., 1996). Feedback should be on the same screen with the question and student response to reduce the memory load on students, should provide hints and ask students to try again if answers are incorrect, and be tailored to the response. Feedback should not encourage students to answer incorrectly just to see the feedback (Orr et al., 1994).

In support of Gagné's framework, the interface can be designed with scaffolding, for example, to *present stimulus with distinctive features* that tells or shows students what to do. According to Jackson, Stratford, Krajcik, and Soloway (1995), users need support for learning how and why to do tasks in the manner for which software was designed. When scaffolding for *tasks*, minimize complexity by providing a simpler set of tasks for learners to perform. When scaffolding for *tools*, provide a range of tools that support different learning styles and different levels of expertise. Some learners may prefer to work verbally, while others prefer more graphically oriented tools. When scaffolding the *interface*, provide a visual structure for using tools and performing tasks. Encourage reflection by providing opportunities for learners to indicate what they are learning as they complete tasks.

An interface design with scaffolding also helps to *stimulate recall of prior learning* and aids *retention and transfer of learning*. Jackson, Krajcik, and Soloway (1998) said that students could develop independent and reflective thinking and learning skills, if software incorporates adaptable scaffolding. Software can be designed to provide advice for self-evaluation to assist learners who might have difficulty making fading decisions. More advanced scaffolding includes fadeable support that enables learners to choose their own level of scaffolding.

Jackson et al. (1998) described supportive, reflective, and intrinsic scaffolding. *Supportive scaffolding* does not change tasks. Guiding, coaching, and modeling messages are used. For example, software might include help that can be faded by clicking onto buttons like *Stop reminding me* or passive messages as *Show me an example*, which are faded by just not being invoked. *Reflective scaffolding* also does not change tasks. This scaffolding elicits information from learners that requires them to think about tasks. Form fill-ins can be used where learners enter responses to questions about subtasks. *Intrinsic scaffolding* changes tasks by reducing their complexity. This scaffolding is like training wheels on a bicycle. Defaults enable novice learners to use only the simplest of tools available. More advanced features are revealed as learners gain expertise. Learners control turning on or off more advanced features that were previously hidden with computer assistance in decision making.

UNIVERSAL DESIGN FOR LEARNING

The field of multimedia ID is still emerging (Atkins, 1993). UDL incorporates learning principles outlined in Park and Hannafin (1993). Materials have multiple supports and scaffolds built in with multiple means of expression and means of representing information, and enable multiple means of engagement (Kurkjian, 1999).

According to Pisha and Coyne (2001), this new paradigm is based on Vygotsky's three conditions for learning: the recognition system, the strategic system, and the engagement system. The recognition system receives and interprets sensory data. As some individuals, such as those who are blind or vision-impaired, are not able to recognize patterns, visual and auditory presentation would support diverse learners' efforts to access meaning. The strategic system enables learners to plan action and act on information. To facilitate this learning, the UDL approach promotes a manageable array of strategy prompts, hints, and models of expert performance inserted directly within digital text. The engagement system strives to accommodate learners' preferences. UDL would provide some latitude for learner choice.

Provisional guidelines for digital content of UDL, which Pisha and Coyne (2001) said needs further research, include suggestions for supporting the recognition, strategic, and engagement systems of learning. In support for recognition of patterns, provide access to a text only version of core content, while maintaining accessibility to graphics and sidebars. Provide an outline view of key topics to help students to learn from text and to help them understand structural cues typically found in headings and subheadings in published text. Promote strategic use of the outline view as an advance organizer prior to reading the full-text version and reading the outline prior to testing. Facilitate and simplify access to reference materials, perhaps by using a unified resource page. Such a page might contain challenging terms, concepts, and links to supplementary information. To provide support for engagement, text readers might be made available and supportive tools for organization and learning, such as online dictionaries, notepads, and concept-mapping software, and pedagogy supporting collaborative learning.

CONCLUSIONS

This investigation has revealed that no one theoretical foundation exists for ID practice that is suitable for all applications (Willis & Wright, 2000). Both behaviorist and cognitive ID approaches value meaningful learning and realistic contexts for application of knowledge and skills (Atkins, 1993). Both recognize the importance of learner motivation and prior experience (Dick, 1996). The essential difference in ID is that behaviorist approaches rely of the notion that human behavior is predictable, but cognitive approaches consider the role of unobservable mental states and introspection, which are part of human behavior (Winn & Snyder, 1996).

Whether designers elect to use a behaviorist or cognitive approach or a mix of the two depends on the nature of the materials to be developed and the context in which materials will be used. Designers have used objectivist models, such as the Dick and Carey instructional systems design model, to create materials focusing on human performance improvement. Constructivist models appeal to educators because of the diversity of learners and the need to motivate and engage them (Dick, 1996). However, the accountability movement in education with its focus on identifying what students must know and be able to do and assessing students for mastery forces designers to write explicit objectives and criterion-referenced test items. It appears that in educational settings a mixed approach to design would be more appropriate. Identify explicit objectives based on learner needs, but use instructional strategies that promote learning and content mastery in authentic settings. The participatory team approach to design featured in the Willis R2D2 model would be appropriate with both formative and summative evaluations applied, as noted beginning with the fourth edition of the Dick and Carey model.

Further, there is an abundance of theoretical frameworks to assist designers in decision making (Willis & Wright, 2000) regarding the development of the interface of a multimedia product. This article illustrated how designers might enhance motivation using strategies from Keller's ARCS model, apply Reigeluth's Elaboration Theory to layer information, create authentic simulations using Merrill's Instructional Transaction Theory, design instructional events in the interface using Gagné's learning hierarchy, and use scaffolding strategies to help individualize instruction.

Finally, this investigation has revealed that theories continually evolve or are revised as a result of research or critique by designers or theorists in the field. According to Dick (1996), it seems inevitable that there will be a blending of behaviorist and cognitive approaches such that the strengths of each will survive in the long term. A converging model is needed that includes elements from various theories that are useful in explaining learning in multimedia environments (Wild & Quinn, 1998). Research for such a model would include developing and testing guidelines for digital content for a UDL that support the recognition, strategic, and engagement systems of learning (Pisha & Coyne, 2001).

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