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Multimedia learning environments: Issues of learner control and navigation

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Abstract. Using schema theory as a framework, we view learning as an active, constructive process. It is affected not only by learners' internal knowledge structures, but by the external constraints of the learning environment as well (Kozma, 1991). This article examines how different internal learner characteristics (e.g., prior knowledge, self efficacy and interest) and different external constraints (e.g., learner control, instructional design and level of control) influence the learning process. Specifically, we address learning from a variety of multimedia environments such as video, hypertexts, kiosks and other hypermedia within a schema theoretic approach that incorporates a constructivist view.

Key words: external constraints, internal learner characteristics, multimedia environments

1. Introduction

According to schema theory, knowledge is internally organized into abstract mental structures called schemata. These schemata are abstract in the sense that they summarize information about objects, events and situations and structured in the sense that they represent associations among their elements (Armbruster, 1986). They are not static entities, however, but dynamic, continually constructed and reconstructed through the processes of assimilation and accommodation. Assimilation is the incorporation of new information into an already existing schema and accommodation represents the process of modifying an existing schema to fit in new information. Knowledge acquisition, as defined within schema theory, can be defined as the process of the interpretation of new information and the assimilation and accommodation of this information into memory structures or schemata (Anderson and Pearson, 1984). It is through the interaction of the new information presented in an instructional environment and an individual's schemata that understanding arises (Fincher-Kiefer, Post, Greene, and Voss, 1988).

Schemata provide information that aid in the interpretation of meaning. That is, as an individual acquires information, there are attempts to match existing schemata with the information represented by the material being examined. As the learner does this, he or she builds a mental concept of their interpretation of the meaning of the content. This concept is constructed partially out of information previously known and partially by the new information presented. It is the processes of building and refining this concept of meaning that allows comprehension to occur (Armbruster, 1986). As such, meaning is not a property of the instructional environment or of the individual, but arises out of the interaction of the two (Wixson and Peters, 1984).

Using schema theory as a framework, we view learning as an active, constructive process. It is affected not only by learners' internal knowledge structures but by the external constraints of the learning environment as well (Kozma, 1991). The following sections of this discussion examine how different internal learner characteristics (e.g., prior knowledge, self-efficacy and interest) and different external constraints (e.g., learner control, instructional design and level of control) influence the learning process. In this discussion we specifically address learning from a variety of multi-media environments such as video, hypertext, kiosk and hypermedia within a schema theoretic approach that incorporates a constructivist view.

Multimedia environments and learner control

By nature, multimedia environments are dramatically different from traditional learning environments. Traditional learning environments, such as textbooks or video cassettes, tend to dictate an established order in which information is acquired and comprehended. As such, what information is learned and the manner in which this information is presented is controlled by the author (i.e., program control). In contrast, multimedia environments are characterized by the ability to present information in a nonlinear or random access fashion. The learner has the opportunity to select what information to access as well as how to sequence the information in a manner that is meaningful to him or her. In essence, the learner is given control over his/her own instruction (i.e., learner control). He/she must navigate the terrain of the multimedia environment, composing a somewhat unique and individual instructional sequence.

The use of learner control or program control may also be described as the locus of instructional control, with the control of instruction classified as either external (program control) or internal (learner control) (Milheim and Azbell, 1988). Hannafin (1984) elaborated upon these definitions, denoting external control as those situations in which all learners follow a specified path established by the instructional designer. Internal locus of instructional control would be illustrated by lessons in which the learner controlled the path, pace and contingencies of instruction.

Cognitive researchers have claimed that learner control is an important aspect of effective learning (Merrill, 1975; Reigeluth and Stein, 1983). Additionally, some constructivist approaches advocate the importance of the ability of the learner to manipulate the instructional environment to construct a personal mental model of the domain (Brown, Collins, and DeGuid, 1989; Bruner, 1973; Wittrock, 1978). Cognitive models of learning have long focused on presenting information in a manner that matches the characteristics of the learner (Bruner, 1973; Cronbach and Snow, 1977; Tobias, 1976, 1981). These models have also argued that the individualization of the instructional sequence (i.e., learner control) may allow the learner to make large advances on his/her own initiative (Brown, Collins, and DeGuid, 1989; Holmes, Robson, and Steward, 1985; Mayer, 1976; Merrill, 1975; Reigeluth and Stein, 1983).

Merrill (1975) suggested that the learner should be given control over the sequence of instructional material. With this control individuals can discover how to learn as they make instructional decisions and experience the results of those decisions. As such, students are able to acquire strategies for learning in different situations. Further, the Component Display Theory of Merrill (1983) and the Elaboration Theory of Reigeluth and Stein (1983) have both indicated that learner control can positively influence effectiveness and efficiency of learning. Additionally, it has been demonstrated for some time that retention and attitudes about a topic were greater for those using learner control (Fowler, 1983; Newkirk, 1973; Ross and Rakow, 1981).

Although there is considerable evidence that learner control can improve student performance (Campizzi, 1978; Gray, 1987) and attitudes (Lahey, Hurlock, and McCann, 1973), and reduces instructional time (Lahey, 1976), there is also evidence that some users of learner controlled environments may not learn as much as those in a program-controlled situation (Fry, 1972; Goetzfried and Hannafin, 1985; Judd, 1972; Steinberg, 1977). Hannafin (1984) suggested that procedural tasks and verbatim learning tasks are best taught using program control. These contrasts may be due to variations in the nature of the learning task (i.e., procedural versus declarative), learner characteristics (e.g., prior knowledge and attitude), the specific instructional designs utilized, the types of learner control offered, and the assessment procedures employed (Hannafin and Sullivan, 1996).

In order to further examine these premises, Shyu and Brown (1992, 1993, 1995) conducted a series of experiments focusing on procedural knowledge by training learners to fold origami (paper folding) cranes. Learner control was available to the learners in the form of content (as selected from a descriptive menu) and display control (as defined by the ability to revisit specific sequences or to select new ones). The learners selected the sequence of the information and decided when they had learned the task sufficiently to be tested. Several different procedures were used to examine the impact of previous knowledge, associated ability (spatial ability), previous training in a related task, and the use of diagrams, on the learner's ability to fold the crane, their attitudes about the instruction and the changes in their self-efficacy for folding an origami crane.

Contrary to Hannafin's (1984) position that procedural tasks would be best taught using program control, the results of Shyu and Brown's work (1992, 1995) indicated that learner control resulted in higher task performance, but did not impact the learner's self-efficacy for the task. Additionally, the results of Shyu and Brown's 1995 study indicated that the learners with greater ability in the content domain were

> more able to make judgments about their progress and monitor their need for instruction, which ultimately resulted in better performance, feeling more favorable about the instruction, feeling more confident in the ability to complete the task, and utilizing the instructional setting more efficiently (p. 225).

The results of the studies by Shyu and Brown (1992, 1995) indicated that all students appear to benefit from learner control opportunities, but that those with higher content domain experience and/or ability may benefit the greatest.

As highlighted in the Shyu and Brown studies, student characteristics such as prior knowledge and attitude can have a profound effect on knowledge acquisition in learner controlled environments. Additionally, Snow (1980) suggested that some students may not be able to make effective use of learner control:

> learner control cannot be expected to overcome the persistent fact that individual characteristics not under the control of the individual will determine to a significant extent what and how much that individual will learn in a given instructional setting (pp. 152–153).

Earlier, Fry (1972) demonstrated that students using learner control actually increased their knowledge when the students had a high aptitude for the domain. Based on this finding, Fry further suggested that learners with high ability in a domain area are better prepared to make decisions about their instructional progress and needs for further instruction, which in turn may result in greater learning. Additionally, Gay (1986) posited that learner control would be more efficient than program control only under the condition that the learners had a well established conceptual understanding of the content domain. Earlier support for this position has been presented by Tobias (1976) and Ross (1984), who both proposed that the higher the prior domain knowledge of an area, the lower the program support necessary to accomplish the objectives. As such, not all learners may reap the same benefits from such instructional freedom. Learners within a multimedia environment must not only understand the information presented, but must also be able to identify what information will further enhance understanding, and how to access this information. In instances where domain knowledge may be very low, for example, novices or naive users may not make certain selections at all, leaving holes in the knowledge base (Barab, Fagen, Kulikowich, and Young, 1996). In other cases, more knowledgeable users may become frustrated with the system as they are presented information they have already mastered as they await the information they are seeking (Lawless and Kulikowich, in press).

An accumulating body of research has also suggested that a learner’s self-efficacy may be impacted by learner control. Self-efficacy is the belief one has about his or her ability to plan and execute a specific behavior (Bandura, 1977), and has been shown to be an excellent predictor of student attitudes and accomplishments (Owen and Froman, 1992; Schunk, 1989). During the surge of interest in the programming language Logo, Papert (1980) argued that by increasing the control learners have over their microworlds, they will enhance attitudes and assist learners in taking independent responsibility for their own learning. Lepper (1985) further suggested that learner control may increase feelings of competence, self-determination, and may increase intrinsic interest.

Given the two sides of the learner control debate, an obvious issue facing instructional designers and users of instructional multimedia becomes control of the information flow. Should the learner have the ability to make selections from a menu in any order he/she wishes, in order to meet their specific instructional needs or should the program have a specified path through the instructional information to insure that all users receive specific information and skills? On one hand, allowing the users free access to the information may meet the immediate needs of the learner and also positively impact his/her self-efficacy and attitudes about using the media. Many cognitive theorists and instructional designers contend that learners who are afforded the opportunity to direct their own learning can process information more deeply and, as such, obtain a better command of the information (Craik and Lockhart, 1972; Fernald, Chiseri, and Lawson, 1975; Merrill, 1975, 1983, 1984; Tulving and Thompson, 1973).

Alternatively, all users of the educational media may not possess the necessary cognitive and affective pre-requisites (i.e., knowledge, motivation, interest) to make informed or correct choices. Allowing the student to follow a specified path of information (i.e., minimal learner control), choosing only to revisit the information or to proceed onto the next step, may be more beneficial than complete autonomy in some cases.

Given the various findings regarding the effects of learner control, the author of a multimedia environment is charged with the task of deciding how much navigational freedom to yield to the learner. The instructional design implemented to create multimedia environments can serve as a guide to knowledge acquisition and information assembly (Wilson and Jonassen, 1989). When the schema theoretic approach is taken for example, multimedia environments tend to emphasize the need to organize information as a compact representation of the knowledge (Shin, Schallert, and Savenye, 1994). However, when a more extreme constructivist approach is taken, the rationale of multimedia instructional tools is the ability to explore and discover complex connections between the content and the goal of the learner (Jonasses and Wang, 1993).

In addition to specifying content arrangement, the design theory used to construct multimedia environments can directly effect a user's instructional choices. Users of schema driven multimedia environments, by nature of design, tend to be more constrained in their navigational efforts. Instructional tools of this nature are commonly hierarchically organized (Jonassen, 1986). That is, information is organized into blocks which can be explored laterally to inspect graded associations between concepts. As such, tangential exploration is much less common. However, with multimedia environments that are more constructivist in nature, less structure is imposed upon the content. Emphasis in constructivist environments is placed on the search for links between complex information. As such, information can be explored both laterally and horizontally (Barab, Bowdish, Young, and Owen, in press). Learners operating in these environments tend to have much more nonlinear navigation paths, discovering potential associations rather than predetermined relationships between concepts (Carver, Lehrer, Connell, and Erickson, 1992).

A third theory of instructional design, the Cognitive Flexibility Theory (CFT) has received a great deal of attention recently (Jacobson and Spiro, 1995). The CFT highlights that the nature of the domain of instruction dictates the design of multimedia learning environments (Spiro, Vispoel, Schmitz, Samarapungavan, and Boerger, 1987). While well-structured domains, such as physics and mathematics, are algorithmic in nature, ill-structured domains (e.g., history and literature) are more heuristic in nature. The more ill-structured the domain of instruction, the more nonlinear the cognitive processing will be (Spiro and Jehng, 1990). The CFT emphasizes the need to implement instructional techniques that compliment the nonlinear nature of processing in ill-structured domains. Techniques such as multiple presentations of information from a variety of perspectives lie at the heart of the CFT (Spiro, Feltovich, Jacobson, and Coulson, 1992). Learners navigating in cognitively flexible learning environments compare and contrast the different perspectives and frequently revisit information with different intentions. As such, CFT environments are less structured than schema theoretic environments, but more structured than strict constructivist environments.

Once the overall scaffolding of a multimedia environment has been identified, designers/authors can also prescribe the level of learner control. There are five basic author imposed control levels: browsing, searching, connecting, collecting and generating (Binder, 1989; Gall and Hannafin, 1994; Grabinger, Dunlap and Jonassen, 1993; Scardamalia and Bereiter, 1992; Wilson and Jonassen, 1989). These levels are hierarchically ordered on the basis of learner control and level of learner interaction. *Browsing* offers the least learner control and is least interactive. Generally, learners browsing through a multimedia environment lack specific intention or a defined goal. The lack of constraints placed upon the browsing learner afford more freedom to explore areas of personal interest. This, however, necessitates a great deal of self-management on the part of the learner to help determine which selection will heighten comprehension. As such, navigation in browsing environments can be haphazard and random. These types of selections often breed incidental learning that is superficial in nature (Kozma, 1991; Park and Hannafin, 1993).

Searching is a slightly more interactive control level, primarily because the learner has a defined goal. Users searching a multimedia environment are attempting to extract information related their specific intentions (Guthrie and Dreher, 1990). For example, a learner using a multimedia encyclopedia may be interested in aggregating all information related to South Africa. Once the information is located, the search process is terminated. The success of the search process is directly related to the efficiency of the information acquisition. As such, search-based exploration is limited to techniques that positively impact the success of the search (Binder, 1989). Search strategies in multimedia environments are increasingly important as the amount of information stored in electronic databases expands.

Connecting and collecting processes tend to be utilized in more interactive navigational environments and are more generative in nature. *Connecting* affords learners the ability to identify new associations between information bits not already linked in the document. The learner is then able to create a permanent hard link in the system to signify the association. This new link is representative of a mental association the learner has established while acquiring the information. Learners engaged in an environment that allows for connecting tend to revisit and review information (Lawless and Kulikowich, 1993). Toggling back and forth between informational segments permits the reader to compare and contrast information to discover linkages.

Collecting information involves the identification of a group of related information segments which maybe textual, graphical, sound bites or other format. This information is then extracted and reassembled into a separate free standing program (Gall and Hannafin, 1994). Like connecting, a collecting environment allows the learner to create a permanent artifact of the learning process. The selections of a student engaged in collecting information vary and are dependent upon the learners intentions for gathering that information.

The final level of control, generative, has been explored by Scardamalia, Bereiter, McLean, Swallow, and Woodruff (1989). Using computer-supported intentional learning environments (CSILE), they have probed the potential of permitting students to go beyond controlling and sequencing the instruction, but also allowing students to contribute to the instructional database. Research findings indicated that the ability to generate and add information to the instructional program enables students to process information at a deeper level (Scardamalia and Bereiter, 1992) and take more ownership over their learning (Barab, Young, and Shaw, 1996).

Navigation

One way to gage the utilization and efficiency of learner controlled multimedia environments is by documenting an individual's movement through these environments. This is commonly referred to as a learner's navigational path (Lawless and Kulikowich, 1993). By collecting information regarding what types of selections an individual makes (i.e., text-based screens, digitized movies), the sequencing of these different screens and the time spent processing the various components of the environment, researchers are afforded a non-intrusive window into knowledge acquisition strategy, information search and problem solving (Barab, Bowdish, Young, and Owen, in press; Guthrie and Dreher, 1990; Lawless and Kulikowich, 1995; in press).

The empirical study of navigation in multimedia environments has been facilitated by the ease with which navigational information can be collected. Using a few simple commands, the author of a multimedia learning environment can embed a data collection program within the text that is transparent to the user. This program can record data pertaining to variables such as time, sequence of information selected, and the nature of these selections. These computerized data banks are commonly referred to as dribble files (Young and Kulikowich, 1992; see Young, Kulikowich, and Barab, this issue).

A review of several articles investigating computerized dribble files (e.g., Anderson-Inman and Horney, 1993; Barab, Bowdish, and Lawless, 1996; Bowdish, Barab, and Lawless, 1994; Lawless and Kulikowich, 1995; in press) reveals at least three common navigational profiles: (1) *knowledge seekers*; (2) *feature explorers*; and, (3) *apathetic users*. *Knowledge seekers* (also referred to as *book lovers*) would seem to typify those individuals who pursue information related to the content of the learning environment. They navigate toward screens that contain material needed to enhance comprehension of a specific domain. Additionally, these learners tend to be more strategic in their path selection, in that they select logical sequences of screens, acquiring information in a systematic manner.

Because hypertexts are a computerized medium, they offer much more dimensionality than do traditional texts. By dimensionality, we refer to the special effects afforded by computer-based documents, such as quick-time movies, sound and visual effects, and graphics. *Feature explorers* (also called *resource junkies*) are those learners who spend a disproportionate amount of time interacting with these special amenities. These individuals seem to invest more time in understanding how the program works and what kinds of screens it contains than in trying to gather important information from the instructional content.

The third navigational profile that is documented in the literature represents the *apathetic users*. These navigators do not appear to care about using the instructional environment either to gather information or to explore its features. In fact, apathetic users are characterized by the short intervals of time they spend interacting with the instructional environment. Additionally, the navigational paths of these individuals appear to be the most linear. Rarely do these individuals deviate from a given path once selected. Further, these individuals seem have no goal or intended outcome. As such, we might say apathetic users are unmotivated to engage in more elaborate and meaningful explorations of the environment.

The study of navigation through dribble files has also enabled the examination of complex learning variables such as problem solving, metacognitive strategies and planning. Lawless and Kulikowich (1994) investigated the influence of navigation on comprehension processes in a hypermedia reading environment, finding that readers who were more knowledgeable and more interested in the content of the instructional environment recalled more information. More importantly however, the influence of knowledge and interest on reading comprehension was mediated by the navigational techniques used. Readers with higher knowledge and interest levels used more efficient navigational techniques to acquire information thereby facilitating comprehension.

In a similar study, Dillon (1991) examined the roles of knowledge and interest on the comprehension of a hypermedia text. Results revealed that individuals with higher topic familiarity struggled less with navigation through the content and thus were able to focus more on areas of interest. Dillon concluded that these individuals learned more from the text than lower knowledge readers who navigated with more difficulty. Both Lawless and Kulikowich (1994), and Dillon (1991) attributed their findings to the greater metacognitive awareness of the high knowledge students in monitoring the structure of the content already acquired and in identifying new linkages between informational units.

These two studies provide evidence that while navigation provides for learner control, the building of sequences of information within multimedia environments may be particularly difficult for learners limited in both domain knowledge and metacognitive skills. Students who do not possess a prerequisite amount of information may get lost in the environment, unable comprehend the information presented, to identify what information is needed or where to locate it (Charney, 1987).

Further evidence has suggested that certain aspects of multimedia environments may actually impede learning. Lawless and Kulikowich (1995) found that certain users of multimedia environments are seduced by the “bells and whistles” of the computerized environment (e.g., sound effects and digitized movies). In this investigation, learners with lower knowledge levels tended to allocate a great deal of attention to these special features, as a result, less of the important text based information was acquired. These results suggest the need for instructional designers to carefully incorporate instructionally sound material into these special features rather than using them to decorate the environment.

When the proper environmental constraints are provided for the learner however, appropriate navigational techniques can be elicited, regardless of prior knowledge level. Barab, Bowdish, Young and Owen (in press) conducted an investigation where individuals were placed into one of two experimental conditions. In one condition, readers were given a problem statement prior to interacting with a multimedia kiosk. Participants in the second condition used the kiosk based on their own interests; no specific task was provided. Individuals in the task-specific condition produced more efficient and a higher quality solution. They spent more time on solution relevant screens and more successfully identified information that was irrelevant or superfluous. Although adoption of a goal significantly impacted navigational performance, no significant prior knowledge differences were found between the two experimental conditions.

A recent study by Jacobson and Spiro (1995) highlights that the opportunity to make navigational choices in multimedia environments extends beyond immediate outcomes such as reading recall tasks and problem solution success. Learners in this investigation were asked to read either a cognitively flexible hypertext or one of two control texts. Results indicated that although the control groups recalled more factual units of information, cognitively flexible hypertext readers had better transfer of knowledge to a novel situation. The authors posit that the ability to take control of learning and acquire information in a flexible manner facilitates knowledge transfer.

Summary

Kozma (1991) purports that learner-controlled multimedia environments challenge learners to develop and use cognitive skills in addition to those used with more traditional learning environments such as textbooks. As can be seen from the research summarized above, the development of these skills is centered around one's ability to make mindful navigational selections. While the ability to control one's instructional sequence can enhance learning and heighten attitudes and self-efficacy, unrestricted control and lack of learning goals can dampen the power of learning in such an environment.

The studies cited and discussed above focus on a specific format of learner control in which the options, speed of access, navigation and available media was quite limited by current standards. In most cases, the amount of learner control and/or navigational control was limited to menu choices made available to the learner. When *surfing the net*, learning information from a on-line instruction complete with audio, text, full-motion video, graphics, and static pictures, or working within a PC-based instructional environment which may use CD-ROM materials, the available options may be very different. As the available technology continues to evolve, so too will the nature of learning and instruction. Researchers must continue to investigate issues of learner control and navigation so that we may be better able to provide appropriate instruction and resources.

As we make decisions as educational psychologists and instructional designers about the types of control and navigation we provide to our learners, and the manner in which we provide these options, we must base these decisions on the latest models of cognitive processing, instruction and associated research data. The instructional materials which we develop must make the best use of this technology within the framework of current learning theories and models. We must be cautious not to make the instructional system fit the technology but make the technology fit the instructional systems and formats that have been demonstrated to be effective. Technology is not effective learning in and of itself, but merely provides a forum for effective learning.

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