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ABSTRACT

The use of hypermedia in education is supported by cognitive flexibility theory which indicates transfer of knowledge to real-world settings is improved when that material is learned in a case-based, associative network emphasizing complexity and links to related information. Hypermedia is further assumed to benefit education, because it resembles models of human memory storage as schemata and mental models. Research on hypermedia has been conducted and influenced its design in the area of links, nodes, navigation, tasks and goals supported, learner differences, and learner control. Despite advances in understanding this technology, it continues to emerge and change, forcing educators to consider new forms of hyper technology such as virtual learning environments. It is argued that virtual learning environments possess substantial new features that improve upon traditional hypermedia. Benefits of emerging virtual learning environments include new metaphors for navigation, better opportunities for knowledge construction, and better opportunities for knowledge transfer. However, future research is called for to more fully understand the potential impact of these features. An analysis of research and theoretical literature in both traditional hypermedia and virtual learning environments is discussed. (Contains 55 references.) (Author/SWC)

A Critical Analysis of Hypermedia and Virtual Learning Environments

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Abstract

The use of hypermedia in education is supported by cognitive flexibility theory which indicates transfer of knowledge to real-world settings is improved when that material is learned in a case-based, associative network emphasizing complexity and links to related information. Hypermedia is further assumed to benefit education, because it resembles models of human memory storage as schemata and mental models. Research on hypermedia has been conducted and influenced its design in the areas of links, nodes, navigation, tasks and goals supported, learner differences, and learner control. Despite advances in understanding this technology, it continues to emerge and change, forcing educators to consider new forms of hyper technology such as virtual learning environments. It is argued that virtual learning environments possess substantial new features that improve upon traditional hypermedia. Benefits of emerging virtual learning environments include new metaphors for navigation, better opportunities for knowledge construction, and better opportunities for knowledge transfer. However, future research is called for to more fully understand the potential impact of these features. An analysis of research and theoretical literature in both traditional hypermedia and virtual learning environments is discussed.

Introduction

Vannevar Bush is often hailed as the first person to consider the use of a hypermedia environment. He wrote of a "memex" machine (Bush, 1945) which allowed a user to traverse microfiche documents using a link and node structure of their own assembly. Other influential innovators in the development of hypermedia include Douglas Engelbart who invented the mouse and multiple-window screens during the 1950s and 60s, Ted Nelson who contrived the term "hypermedia" in the early 1970s as applied to his Xanadu Project, and Alan Kay who built a hypermedia prototype out of cardboard called the Dynabook in 1968 (Cotton & Oliver, 1993).

What these innovators could not have possibly imagined is the scope and widespread integration of their early fantasies and designs. Through multimedia CD-Rom and hypermedia distribution systems such as the World Wide Web, it is very possible if not inevitable that every person on the planet will someday be traversing links and nodes of hyper systems at work, school, and play. What is important, then, especially for educators, is to understand hypermedia. A need exists to understand how hypermedia can promote learning, how to design and develop hyper systems, and how learners feel about and use hyper systems. Fortunately, a great deal of theory has been developed and research conducted in these areas.

Defining Traits of Hypermedia

Defining Hypertext, Hypermedia, and Multimedia

Conducting a literature review on hypermedia can be confusing due to the fact that the term is often used interchangeably with several others including hypertext and multimedia. Different groups use different terms when they essentially are referring to the same types of hyper systems. The academic community tends to use the term hypermedia while those in business seem to prefer the term multimedia (Reeves & Harmon, 1991). Those using the term hypermedia tend to emphasize the medium's link and node structure whereas those using the term multimedia prefer to emphasize the combination of text with graphics, video, and sound. Tolhurst (1995) provides an excellent framework for considering the terms. She refers to hypertext as link-node systems that use only text, photos, and graphics--the same items that can be found on a traditional printed page.

Hypermedia is defined as a link-node system incorporating hypertext along with other non-print media such as video and sound. The addition of time-dependent media (McKerlie & Preece, 1993, p.38; Cotton & Oliver, 1993, p.64) into the presentation separates hypermedia from hypertext. Multimedia is defined as a broad catch-all term for any learning environment containing more than two types of media (e.g., text, graphics, animation, sound) (Reeves & Harmon, 1991; Tolhurst, 1995; McKerlie & Preece, 1993). Note that multimedia is not necessarily hyper with a link-node structure that involves some degree of interactivity, but hypertext and hypermedia are almost always "multi" media and subsumed under that larger heading.

The lack of consensus in defining the terms stems from the fact that technological systems once capable of only hypertext displays are now more advanced and capable of increasingly complex components such as video, sound, and explorable virtual worlds. Hypermedia has very loosely defined boundaries that constantly change, subdivide, and evolve into new forms of technology. A good example is the static photograph that was once only displayed on a page of text or in a hypertext system, and is now capable of being shot in 360 degrees, explored, rotated, linked, and expanded with Apple's QuickTime VR (virtual reality) technology. While it is unlikely that any one definition will suit all needs and preferences, understanding the evolution of these terms and their primary components helps set the framework for study in this dynamic area.

Characteristics of Hypermedia

Currently, hypermedia primarily consists of a set of modularized nodes strung together by associative links (Jonassen, 1989) that provide a web of information for a user to dynamically interact with. Caution is suggested, however, in narrowly defining hypermedia as modularized, because new, virtual interfaces are being developed which make paging through separate nodes less obvious than simply clicking a button or word to open another separate and distinct screen of information (see Virtual Learning Environments later in this paper). Another important characteristic of hypermedia is its ability to provide for connections.

What one might find in a node varies widely and increasingly. Cotton and Oliver (1993) suggest several common components of hypermedia: an interface with visual metaphors and control devices used to navigate through the system; images in the form of photographs, illustrations, graphics, and paintings; text and typography; audio; video; animations; and virtual spaces. Information encoded in these media formats may either be "presentational" (e.g., spoken words and gestures) which are communicated ideas, or "representational" (e.g., text and graphics) which are encoded and used to symbolize ideas (Rada, 1995, p. 6). These media can be further broken down into time-dependent formats that are typically presentational (e.g., video and audio) and static formats (e.g., text) that are typically representational.

A number of authors (Marchionini, 1988; Lee & Lehman, 1993) classified links as either implicit or explicit. Marchionini (1988) states implicit links take one to support materials such as dictionaries and explicit links take one to further information that clarifies or supports an original idea. Lee and Lehman (1993, p. 29) state implicit links are "attached to specific information on the screen" such as "hot words" designated to link a user to elaborative information on specific topics, and explicit links are graphic icons, "plainly visible on the screen," used for navigation. Links are activated via textual elements, graphical icons, or other interface options a user typically clicks on with a mouse to move from one node to another. As Locatis, Letourneau, and Banvard (1989, p. 65) note,

> Color coding, icons, cursor changes, and other screen design devices are used to indicate which display elements constitute links.

Links should not be thought of as an icon, however, but rather in terms of the functions they perform. Stanton and Baber (1994, p. 236) list nine common link functions: provide more information about, provide contrast/perspective, link to a related node, return to a previously accessed node, given an example, animate something, provide pop up information within the current screen, return to the home page or first page accessed, and exit. In contrasting links and nodes, Stanton and Baber (1994, p. 237) point out that "nodes can be quite easily designed" by their information presentation (e.g., text, diagram), thus most of the emphasis in current hypertext design is "on links rather than nodes."

Nodes and links together form a network or web of ideas (Jonassen, 1989). These webs can take on a variety of structures (see Structure later in this paper) and are related by many (Kearsley, 1988; Dede, 1987; Dede, 1992) to how knowledge is stored in our long-term, semantic memory. The idea of a web of knowledge is not necessarily a new one, but it is certainly being made more efficient with hypermedia technology. As Bevilacqua (1989, p. 161) suggests, the print domain previously contained referential elements to which or from which one could "link" including tables of contents, indexes, footnotes, bookmarks, and even post-it notes.

Hypermedia further provides for an interactive environment in which the user typically has a great deal of learner control over the information presentation (see Learner Control later in this paper). Nielsen (1995) suggests that potentially hyper formats such as multimedia and interactive video should not necessarily be classified as hypermedia. What makes these formats hyper is their ability to provide the learner with some degree of control and interaction within the environment, not just sitting passively and watching a presentation like television programming. The television format has multiple media (sound, graphics, text, video), but it is traditionally not interactive.

A final hypermedia characteristic is its ability to provide one with multiple connections. Dede (1987, p. 23) points out that society has "five primary educational agents: schools, family, community, media, and workplace." Hypermedia enhances our ability to reach out, pull resources, and connect with each of these educational agents through distributed learning environments like the World Wide Web.

Learning Theory and Models Supporting the Use of Hypermedia

Cognitive Flexibility Theory

One traditional approach to handling complex knowledge is to break it down into simplified parts and teach segmented knowledge apart from the whole (Jonassen, Ambruso, & Olesen, 1992). According to Jonassen et al. (1992, p. 310), this is a "reductive bias" that may lessen cognitive load on learners, make it easier for them to write about the concepts or study them, but it also rigidly packages the content and discourages adaptation to real-world contexts outside of the instructional setting.

Cognitive flexibility theory (see Jacobson & Spiro, 1995; Jacobson, 1994) is a model for designing instruction that allows a learner to transfer complex knowledge from an instructional setting to a real setting. It has five basic principles: using multiple representations of knowledge (various analogies and points of view); using case studies to demonstrate a variety of applications of the same knowledge; making use of complexity (not decontextualizing the knowledge by breaking it down); stressing the cross-associational, web-like nature of the context to demonstrate its flexibility in and applicability to a variety of settings; and involving the learner is knowledge construction by providing them with tasks or applications to which they must apply the knowledge (Jacobson & Spiro, 1995). Flexibility theory has been hailed by some (Jonassen et al., 1992, p. 315) as "a cognitively based theory of knowledge acquisition that provides one of the best conceptual models for designing hypertexts."

Jonassen et al. (1992, p. 313), in citing several studies, point out "research has provided consistent empirical support for the theoretical predictions of cognitive flexibility theory." That is, flexibility materials encourage the transfer of knowledge to a variety of settings, whereas traditional materials enable students to recite and memorize facts and figures more effectively.

Ambrose (1991, p. 54) poses the question, "does the use of hypermedia materials encourage learners to employ higher level thinking skills?" Marchionini (1988, p. 9) suggests hypermedia requires learners to "constantly make decisions and evaluate progress, thus forcing students to apply higher order thinking skills."

Dede (1987, p. 23) defines hypermedia as a cognition enhancer and suggests these environments can complement human strengths of "creativity, flexibility, decision making, complex pattern recognition, information evaluation, synthesis, and holistic thinking." With cognitive enhancers like hypermedia providing a base of lower-order facts, students can focus on polishing their strengths and acquiring the higher-order skills just mentioned. Dede (1992, p. 54) further mentions:

> Learners frequently become lost in a morass of data from texts and from inquiry projects. Without higher-order thinking skills, they cannot synthesize large volumes of information into overarching knowledge structures.

A question to consider then, is whether or not large hypermedia environments allow learners to become more flexible learners and build their higher-order skills. If as Dede suggests, learners are unable to synthesize large volumes of information without higher-order skills, is it likely to believe they will acquire higher-order skills through interactions with voluminous hyper environments when they can't yet synthesize that information? Perhaps it is through the struggle to synthesize vast domains of knowledge students acquire higher-order skills. But is this universal, or only for certain learners? Research discussed later in this paper (see Learner Differences), suggests only learners who can be classified as "active" are capable of efficiently managing the increased freedom brought about by hypermedia without additional support tools.

Schemata and Mental Models

Schemata are the interrelated, web-like knowledge structures we have developed in our minds. According to Jonassen (1988, p. 13), they are comprised of various attributes which "are the associations that an individual forms around an idea." As Jonassen (1988, p. 13) further notes,

> Our schemata for "firetruck," for instance, is comprised of attributes such as red, hoses, ladders, large truck, sirens, as well as other associations such as firemen, dalmation dogs, fire hydrants, insurance, etc.

Learning takes place when an individual successfully takes a new attribute or chunk of knowledge and links it with a pre-existing knowledge structure or schemata.

A mental model can be thought of as one individual's understanding of how something works, is sequenced, should be approached, should be avoided, etc. According to Kearsley (1996), these "understandings" are frequently "incomplete and constantly evolving," "typically contain errors and contradictions," and "provide simplified explanations of complex phenomena." A mental model for hypermedia, according to Jih and Reeves (1992, p. 45), might include "structures reflecting users' understanding of what the system contains, how it works, how components are related, what the internal processes are, and why the systems works the way that it does." To measure a learner's mental model of hypermedia, Jih and Reeves (1992, p. 47) suggest asking the learner to describe or explain the system or predict how the system will behave, observe the learner using the system, and observe the learner teaching the system to another person. Jih and Reeves (1992) point out important differences between studying a user's mental model of hypermedia systems versus their mental model of the content being learned. The authors suggest future research be conducted in this area to determine mental models learners form of hypermedia, what those impart about current hyper design, and how they can inform future hyper designs.

Models of Memory

Recent models of memory have emerged to represent how knowledge is stored and retrieved from our long-term memory. These models support the idea of schemata and web-like knowledge structures that make up long-term memory, and thus, support the idea that we might learn better from environments that are similarly structured such as hypermedia.

The network model of memory (Bruning, Schraw, & Ronning, 1995) suggests memory is stored in nodes (concepts, schemata) that are connected by links of association. Similar to the network model is the Adaptive Character of Thought Model (Anderson, 1990) which suggests memory is stored in units (propositions) that are connected by "the relation and arguments of the proposition" (Bruning et al., 1995, p. 71).

Both of these models operate under the concept of "spreading activation" which suggests that a node or unit is activated by some perceived stimulus (e.g., car horn), then our memory is activated at a point containing that bit of information (Bruning et al., 1995, p. 68). If we have stored related structures and arguments that are linked to the activation point, our search for information related to understanding the stimulus will spread outward through our mind. Spreading is thought to occur in parallel fashion, moving from the activation point in several outward directions simultaneously (Bruning et al., 1995).

Hypermedia Design Implications

Authoring Hypermedia

Jonassen (1988, p. 14) states, "hypertext . . . poses as many dilemmas for the author as it does for the users." According to Staninger (1994), hypertext structures are different from textbooks and other media that deliver one person's thoughts to many. Instead, these databases require authors to predict what users will do with cross-associated information, which links they will take, how that information supports the original content, etc. As McKerlie and Preece (1993, p. 35) note,

> Designers cannot change the goals of the users..., but they can change the design so that the tasks which users carry out (e.g. navigating) are more suited to the goals and experiences which the users bring to the application.

Jonassen (1988) indicates there are at least two ways one can design hypermedia structures: inductive, and deductive.

The inductive method is a hypermedia structure based on the learner. Studies are initially conducted determining the paths users are most likely to take by recording the link-node trails they follow. Learners are subsequently assigned to hypermedia structures in the future that most closely match "their preferred learning styles or provide the learners control of their choice" (Jonassen, 1988, p. 15). Jonassen (1988, p. 15) notes,

> Preferential matching of learners to instructional treatments based upon their individual knowledge structures has been the theoretical goal of designers of intelligent systems. Hypertext provides that possibility.

Inductive models are more constructivistic in nature, working under the assumption that "we each individually construct meaning (in the form of schemata) for objects or events based upon our experiences that we relate to them" (Jonassen, 1992, p. 312).

McKerlie and Preece (1993, p. 43) describe a model of authoring hypermedia that is closely related to the inductive approach "based on the exploration trails of readers." As users work their way through a series of linear documents, a new hypertext document emerges based on the various paths taken. A classroom of 30 students working with the same collection of linear documents, then, would likely have 30 different hyper structures formed from the bits and pieces of knowledge accessed by the students.

The deductive, top-down method is more traditional and attempts to map an expert's knowledge structure onto the learner (Jonassen, 1988). Initial steps in this method are to conduct an instructional analysis, define the expert's knowledge, and break it down into "a series of if-then rules" which are ultimately transferred to the hypermedia structure (Jonassen, 1988). Deductive models are more objectivistic in nature, assuming their is one right way to teach a knowledge domain with less emphasis on the individual learner. McKerlie and Preece (1993, p. 43) refer to this model of authoring hypermedia as "shred and thread" where existing linear documents are decomposed and recomposed into a hyper structure where "the multiple relationships between ideas and concepts" is made explicit via a newly formed link structure.

Differences in professional opinion exist in deciding the utility of applying instructional design and instructional systems design models to hypermedia. Marchionini (1988, p. 11) feels an exploratory approach to hypermedia should be followed, allowing students to learn by "connecting concepts..., forming interpretations, and synthesizing information." Marchinoni (1988) suggests writing objectives for hypermedia is difficult for these types of tasks that involve higher-order thinking skills in relation to subjective, individually-defined problems. Perhaps, then, hypermedia developers should not try to map objectives and task-analyzed, chunks of information onto hyper systems, but rather, should promote more open-ended learning that "guide learners in invoking their own strategies and generating their own learning sequences" (Hannafin, 1996). As Hannafin (1996) suggests, the narrowly-defined model of "how people learn...is not the same as...if people can learn in particular ways."

Still, there are some (Morariu, 1988, p. 19) that suggest, "the introduction of a better tool does not necessarily change the process," and that "hypermedia...is not the panacea for the design of effective learner-directed, computer-based instruction." Morariu (1988, p. 19) presents a traditional instructional systems design model for designing and developing a hypertext structure, and suggests "unless we can 'chart' a learner's course through the information, how can we determine effective tools for measuring their learning." It is worth asking, then, is there one objective measure of learning, or as open-ended environments suggest, several? The answer is most likely task-dependent. Marchionini (1988, p. 11) describes this argument as the "classic tension" between providing learners with "great freedom to direct their own learning and assuring society that all students learn a common body of skills, concepts, and principles." Morariu (1988, p. 19) further warns against learners developing "false concepts through unique links and associations"--an argument partially refuted by Mayes, Kibby, & Anderson (1990) who suggest some degree of disorientation and struggle to build associations between content allows the learner to map out their own mental model.

Nelson and Palumbo (1992) suggest there are three types of hypermedia systems that can be authored: knowledge presentation systems, knowledge representation systems, and knowledge construction systems. Knowledge presentation systems are the most deductive and simply present information established by an author. Nelson and Palumbo (1992, p. 292-293) cite studies indicating learners are typically asked to browse and search presentation systems and that these goals do not promote learning. In order to successfully utilize a knowledge presentation system, then, designers "need to provide specific learner activities focusing on relationships between the information" (Nelson and Palumbo, 1992, p. 293). A task that can be accomplished with the use of "guided tours" through the information to ensure all content is viewed, in a certain order, and not haphazardly. A second type of hypermedia system is the knowledge representation system. Representation systems place less emphasis on node design than presentation systems. That is, they tend to emphasize the value of links and explicitly label the type of information contained via a link (e.g., "definitions, examples, related ideas, applications, elaborations, etc.") (Nelson and Palumbo, 1992, p. 294). The main idea, according to Nelson and Palumbo (1992, p. 294), is to provide "more complex connections between units of information," because,

> It is clear that simply stating that a node "apple" is associated with a node "fruit" does not convey as much information as stating that "apple" is an example of "fruit."

The final type of hypermedia system is the knowledge construction system in which learners are allowed to alter the hyper structure, making and deleting links as discussed above.

Node Design

Node design refers to the visual design and human-computer interface design that developers of hyper systems must take into account. Jacques, Nonnecke, McKerlie, and Preece (1993, p. 224) point out that "presentation issues include the style and use of text, graphics, sound, animation, and video." Gygi (1990, p. 287) notes, "new media will lead to new forms of literacy," but cautions that this advance will either be an "insurmountable hurdle" or a "breakthrough" depending upon "the skill and care of the designers of hypermedia interfaces."

The new ability to integrate time-dependent media into presentations with static text and images has created a variety of new decisions for hyper developers to consider: the need to choose appropriate media for conveying ideas, and the need to establish new conventions for users to perceive those ideas accurately. In describing the need for new conventions, McKerlie and Preece (1993, p. 35) point out that,

> Users are accustomed to...textual conventions which make some words or phrases distinctive from the body of the text. We expect that similar aids or perceptual cues are necessary for information presented in different media formats, especially when text, sound, graphics, and video are presented simultaneously.

Using established conventions such as pull-down menus, buttons, and arrows is one way to ensure users will not become confused, but adopting these "cornerstones of usability and interface design" may be somewhat limiting as they "may not be well suited" to new media formats (McKerlie and Preece, 1993, p. 39). Jih and Reeves (1992, p. 42) concur that "the structure of screen displays in interactive learning systems is not the same as that of print." Jih and Reeves (1992, p. 42) point out,

> Learners must use unique navigation or interaction aids in interactive learning systems, e.g., keyword searching instead of indexes, and icons and menus instead of headings and subheadings. Considerable learning is required as learners begin to interact with hypertext-based interactive learning systems for the first time.

Marchionini (1988, p. 9) suggests a new form of hypermedia literacy is required when he states,

> If large amounts of our reading in the future will be done in electronic form, not guided or constrained by the linear flow of printed text, entirely new strategies may be needed.

Nielsen (1995, p. 8) describes the Elastic Charles project created at the M.I.T. Media Lab, and the new iconic conventions being used to denote a link to a video clip: "micons," or small moving icons that display a miniaturized version of the video at the other end of the link. More common in hypermedia and more confusing to users, however, are what Nielsen (1995, p. 10) describes as "visual surrogate representations." These are typically "hot" words that are clicked on to link one to a node that may contain a graphic, a sound, or a video. Using an iconic convention representing the media type at the other end of a link might help users make more appropriate link choices and better prepare them for processing that information.

Jacques et al. (1993, p. 224) discuss the need for media integration guidelines:

> What appears to be lacking in hypermedia design are established rules or heuristics for matching content with medium type (e.g. actions may be better conveyed through

video than text).

Rada (1995, p. 15) further points out "the presentation of multiple media at the same time may be crucial to the intended meaning and the author must be able to determine what does or does not remain on the screen." To help a user maintain attention on a particular task, McKerlie and Preece (1993, p. 36) suggest limiting "competing messages presented by different media simultaneously," and urge hypermedia authors to "consider competing tasks which also demand attention."

Locatis et al. (1989) note that hypermedia authors must decide the size of their individual nodes, whether or not to nest windows and multiple nodes within one another, and then consider the content that fits into the various nodes. Kearsley (1988) mentions that the readability of computer screens is 30 percent slower than that of print-based material, thus authors must consider the use of uncluttered and concise screen design. The degree to which content is split up into separate nodes is referred to as "content granularity" by Locatis et al. (1989). Nodes can become too small and granular, requiring a user to make constant, confusing jumps to related data. On the other hand, nodes can become too large, requiring a user to filter out irrelevant data. As it becomes feasible to link to increasingly different types of nodes (video, sound, text), it will become necessary for authors to "have facilities for declaring and displaying node types so that node content...might be indicated automatically in links referencing them" (Locatis et al., 1989, p.68).

Locatis et al. (1989, p. 70) further discuss the authoring of links in hypermedia, and provide these suggestions: just because a reference is made to another node does not mean a link has to be generated, and perhaps referential links should be made only once to avoid redundancy (the first time they are mentioned). Locatis et al. (1989, p. 71) use the term "bounding" to refer to the tendency to interrelate all content with hyperlinks--a problem because all knowledge is eventually interrelated and authors must choose when to construct their links.

Rada (1995, p. 2) discusses several ways to distinguish links including those that simply "connect nodes from those that invoke programs," and also those links that were manually programmed by an author to be clicked upon from those that are automatic links based on a computation scheme of predefined rules (if a user does this...then they are linked here).

To reduce load on memory, McKerlie and Preece (1993, p. 36) suggest "selecting meaningful menu and command names, using icons for representing concrete concepts, and consistent placement and behavior of interface objects." Rada (1995, p. 5) suggests these guidelines for intuitive interface design: use a layout that draws attention to links and important content; if you use one convention to indicate a type of link (bold words), don't use that convention again to mean something different; and, use distinct conventions for each link type employed (e.g., video, audio).

Is there a certain type of content that is more suitable for hypermedia than others? Locatis et al. (1989) suggest highly modularized information, used for reference, and frequently browsed, represents the ideal content for transferring to a hyper structure (e.g., dictionaries, manuals, documentation). Locatis et al. (1989, p. 69) suggest, "literary and dramatic works, where character development and a story line are essential, are less appropriate." However, Mclellan (1993, p. 240) would disagree, pointing out "the story format offers several potential advantages as a cornerstone for instructional design in hypertext," including a "familiar information structure" that supports comprehension, reduces cognitive load, and provides for "covert interactivity." Mclellan (1993) cites Roger Schank's work with scripts and stories as well as John Seeley Brown's work with situated cognition as popular movements in education emphasizing authentic, real-world environments for learning. Mclellan (1993) suggests the story format, in particular interactive fiction, be used as an anchor for hypermedia designers. It provides the authentic format that others suggest promotes learning. Interactive fiction is described as one type of hypermedia program where many possible branches can be taken in the story, and each learner comes away with a different experience and different meaning. Virtual environments, discussed later in this paper, are related to the story format as another potential design metaphor for making hyper structures more familiar and navigable.

Structure--Linking Nodes Together

Structure refers to the "topology of the nodes and links" and how they are "conveyed to the user" (Jacques et al., 1993, p. 223). Three types of structures are most evident in hypermedia systems: linear, hierarchical, and network. Helping a user to understand how materials are structured allows them "to build a mental model of relationships within the content, which supports learning" (Jacques et al., 1993, p. 228). Jonassen (1988, p. 13) points out, "the less structured the hypertext is, the less likely users are to integrate what they have learned" into their existing schematic framework.

Linear hyper structures are the simplest to understand, as they simply flow from one screen or chunk of information to the next, typically in a loop. As Jacques et al. (1993) point out, however, "navigation tends to be slow in large hyper-systems as users have to systematically pass through all the cards previous to the one they want." Further, according to Jacques et al. (1993),

The linear structure also reinforces linear relationships among ideas.

Hierarchical structures are subdivided into logical sections, usually with major topic area headings under which lie several related screens or chunks of information. Hierarchical links allow one to access only nodes "directly below or above it" in an organized scheme (Locatis et al., 1989, p. 68). According to Rada (1995, p. 6), as the number of hierarchical levels in a hyper system increase, so will user "performance time and errors."

Network hypermedia structures are more chaotic with random links jumping from one topic area to another. Network links allow one to link from one node to any other node in a less structured, more "referential" fashion (Locatis et al., 1989. p. 68).

In hypermedia, as Jacques et al. (1993, p. 228) point out, hierarchical structures quickly turn to network structures when they begin to employ "cross-associational links between levels and sections." It is easier for users to build a mental model of relationships between nodes of information in hierarchical structures than in network structures (Jacques et al., 1993).

In comparing the three types of structures, Jacques et al. (1993) discovered that linear structures are the easiest to understand but are very inflexible. Hierarchical structures are easier to understand than network structures, provide the user with a good mental model of the overall content structure, and along with network structures are more flexible for exploration than linear structures.

Locatis et al. (1989) describe three types of knowledge representations or ways to structure content in hypermedia. First, an author can structure information hierarchically as described above. Second, an author can structure content elaboratively by simple knowledge on one level of nodes that are elaborated upon with increasingly complex nodes. Finally, a hypermedia author might choose represent knowledge in a conversational fashion--having a base of expert knowledge with links to further information representing various student questions and instructor or tutor replies.

Nelson and Palumbo (1992) suggest structuring knowledge representationally with explicit link information (e.g., click here for an elaboration, definition, example, etc.) provides a user with more helpful information than a presentational structure that emphasizes separated node content. Kearsley (1988, p. 23) concurs with Nelson and Palumbo's emphasis on links over nodes in that "hypertext should improve learning because it focuses attention on the relationships between ideas rather than isolated facts," because "associations provided by links in a database should facilitate remembering, concept formation, and understanding."

Cognitive Load--Scope

Dede (1992, p. 55) suggests that the "nonlinear nature of hypermedia mirrors the structure of human long-term memory, lessening users' need to map from how computers represent data to how people store information," and "the capability of hypermedia to reveal and conceal the complexity of its content lessens the cognitive load on users of this medium, thereby enhancing their ability to assimilate and manipulate ideas."

As mentioned previously, however, when hypermedia approaches a network structure and the user is faced with many potential links to take, a learner's maximum cognitive load can become filled. As Jonassen (1988, p. 14) notes,

> The exponentially greater number of learning options available to learners places increased cognitive demands upon the learners that they are often unable to fulfill.

McKerlie and Preece (1993, p. 36) state that hypermedia often provides for simultaneous presentation of unrelated, multiple media formats which "can divide users' attention between competing media and between competing tasks (e.g. understanding content vs. making link decisions)." Further, McKerlie and Preece (1993) note that hypermedia can place additional demands on a user's memory with link processing requirements.

Jih and Reeves (1992, p. 43) suggest three types of cognitive load, including: "the content of the information, the structure of the program, and the response strategies available." These roughly correspond and point out the connections of cognitive load to design implications already discussed in this section of the paper, including: node design, structure, and linking nodes together. Jih and Reeves (1992, p. 44) note that "risks of confusion are especially high when users confront hypertext materials, which by their very nature include more interactive options than other types of interactive learning systems." Over time, as users build accurate mental models of hypertext systems, short-term memory requirements taken up by struggling with program structure and response strategies are minimized as learners begin to automatize certain tasks. This frees up cognitive space for dealing with more important issues of hypothesis testing and knowledge integration.

Suggestions for helping users manage a large hyper structure are discussed in the upcoming navigation section. Other suggestions for managing this related issue of cognitive load include the provision of "interactive tools" with a hypermedia program that allow users to create bookmarks, write annotations, construct timelines and organizational charts, and make new links of their own (Search, 1993, p. 372). Referring back to the inductive authoring model, these tools are constructive in nature, rely upon the learner to actively process information accessed in hypermedia, and are different from the deductive navigation strategies suggested below that are largely contrived by the author of the hyper structure, not the user.

Navigation Strategies

Jonassen et al. (1992, p. 314) note that "most hypertexts provide an array of options to the user; however, they typically provide no suggestions about where the user should begin." Jonassen et al. (1993, p. 314) further discuss navigation in hypertext:

> Hypertext documents often contain thousands of nodes, each with multiple links to other nodes. It is easy for users to get lost in that morass of information.

Elaborating on the complexity of hypermedia navigation, McKerlie and Preece (1993, p. 37) note that for a user to successfully navigate through hypermedia, they must be able to answer several questions: "where am I, how did I get here, what can I do here, where can I get to, how do I go there, what else have I seen so far, what else is there for me to see?" To help users answer these questions and to allow them to cognitively manage a hyper structure, hypermedia authors employ a variety of navigation strategies including: guided tours; various links; maps/overview diagrams; indexes/tables of contents; landmarks; and dynamic, user-informed navigation methods.

Guided Tours

Stanton and Baber (1994) discuss the guided tour navigation strategy which they suggest is an invalid approach to helping users cognitively manage hypermedia. The guided tour virtually eliminates the need for navigation as the user is not in control. Stanton and Baber (1994) argue that this approach disallows the incorporation of learner control into a hypertext environment which can be motivational, and they also mention that a guided tour reduces a hypertext structure considerably--making it more linear in form.

Rada (1995) describes an navigation strategy referred to as the "travel metaphor" in which a user is initially coached or guided around the hyper structure when they choose this help feature. Experiments (Rada, 1995, p. 6) demonstrate that this type of navigation strategy allows for "more accurate overviews" of the available material and resulted in a higher rate of exposure to new rather than repeated information."

Nelson and Palumbo (1992) suggest guides are an appropriate navigation strategy when the structure of a hypermedia database is one of knowledge presentation. Without guides in these types of hyper designs, users tend to browse and search through information--actions that do not promote learning, perhaps due to disorientation. Oren, Salomon, Kreitman, and Don (1990, p. 381) discuss the use of guides that can "alter the user's course through the data," and "offer alternate views of the content through the stories they tell"--actions that ensure users are at least exposed to a certain amount of content and in some intuitive order. The "canned" guide (Oren et al., 1990, p. 381) that simply carries out predefined tasks is not to be confused with the more powerful intelligent agent or "interface agent" (see Laurel, 1990, p. 356) that uses artificial intelligence to filter and produce information requested from a user. Agents respond more directly to a learner's requirements and would be more useful in helping a user construct their own knowledge than would a guide. Due to the difficulty in developing artificial intelligence, few articles discussing the potential for agents to influence hypermedia navigation or usage were found--a relatively new and unresearched area.

Various Links

Hypermedia authors can further aid navigation by employing a variety of links which allow their users to move around seamlessly. As mentioned previously, nine common links an author can employ include: provide more information about, provide contrast/perspective, link to a related node, return to a previously accessed node, given an example, animate something, provide pop up information within the current screen, return to the home page or first page accessed, and exit (Stanton & Baber, 1994, p. 236).

Locatis et al. (1989) suggest allowing a user to back up to previously accessed nodes and to reach central starting points from any node in the hyper structure will help navigation. In a study of hypertext usability, Nielsen (1990) found that users who were allowed to backtrack to previous nodes were often taken back to a point in the initial node that was not identical to the point where they linked out. This factor appeared to cause some confusion among the hypertext users.

Simpson and McKnight (1990, p. 81) found the provision of a "footprint" that enabled users to return to previously accessed nodes enhanced the efficiency of their navigation but had no effect on one's ability to later structure the accessed knowledge in a map construction activity.

Maps and Overview Diagrams

Maps and overview diagrams are other conventions suggested in the literature for providing information to users on the scope of or their progress through hypermedia. Considerable differences of opinion exist in the literature on the ability of maps and overviews to aid users' navigation.

Search (1993, p. 375) maintains "spatiotemporal overviews" of content that define the organizational hierarchy as well as the number and type of resources give the user "an idea of the amount of time needed to navigate through the database." Search (1993, p. 376) points out, however, that organizational charts and "database diagrams that depict the predefined links in the program [negatively] underscore the editor's perspective not the user's perception of the conceptual relationships in the database."

Stanton and Baber (1994, p. 241) "strongly take issue with the claims made for navigation aids," and further state "maps do not provide useful information." Stanton and Baber (1994) point out,

> If there can be more than one "route" to a piece of information, and if there can be more than one "route" away from that information, how can users develop a map which is sufficiently complex to show the possible routes, and yet be sufficiently simple to permit ease of recall?

Stanton, Taylor, and Tweedie (1992) further show maps can reduce a user's perception that they are in control and can hinder their ability to create individual cognitive maps versus the one designed by the author to facilitate navigation. Stanton and Baber (1994) point out that several research studies dealing with maps were conducted with small, easily navigable hypertext structures. These studies show hypertext users with maps performed better than hypertext users without maps, but Stanton and Baber (1994, p. 243) argue that these results occur only "when there are fixed and invariate relationships between objects" or nodes. In other words, the majority of hypertext structures are more complex than the designs of these studies. In large hypertext structures, then, providing "route or survey information is both misleading and mistaken" (Stanton & Baber, 1994, p. 243).

Nielsen (1995) suggests more hypermedia authors should employ an navigation strategy referred to as the "dynamic overview." The dynamic overview provides a user with a diagram of the hyper system, but the map changes as the user works through the structure to represent the "local neighborhood surrounding the user's current location" (Nielsen, 1995, p. 3). Since it would be impractical and potentially discouraging to display a map with hundreds or thousands of nodes, only a small subset of the entire system is revealed at any one time. Search (1993, p. 377) concurs that the use of maps to indicate "you are here" confuses the learner as it "tries to fulfill too many objectives." That is, a map attempting to show all remaining links or all associative links is doomed to fail related to its required size.

Indexes, Tables of Contents

Stanton and Baber (1994) cite research evidence indicating users' spend disproportionate amounts of time in indexes and contents pages and tend to access them more than necessary when provided as navigation strategies. For similar reasons, Simpson and McKnight (1990) designed a hypertext document with a non-interactive index and contents list, citing evidence by Monk, Walsh, & Dix (1988) that users gain more knowledge from linking within and among the text screens than linking directly in and out of screens from an interactive index or contents page.

In a comparison of a hierarchical contents list with an alphabetical index, Simpson and McKnight (1990) found navigation to be more efficient and users' conceptions of content to be more accurate with a hierarchical contents list.

Wright and Lickorish (1990) sought to determine the effects of removing link decisions from within a hypertext on navigation. A study was designed to compare hypertext navigation in programs using interactive indexes with no in-text linking versus those with non-interactive indexes with in-text linking. Results are task specific and show for tasks where users are uncertain about where to go in a hyper structure, the "close coupling" of an interactive index with the hypertext aided navigation more than random access through in-text links. These are situations where users are essentially searching and browsing. In tasks where users are certain about where they need to go (e.g., searching for a specific footnote or cross-reference), separating navigation from within the text and removing it to an index only hindered users' navigation. The separation made it necessary for users to take notes, as it increased demands on their working memory.

Landmarks

Landmarks are typographical cues (e.g., headings, illustrations) or other audio-visual stimuli (e.g., video clips, sound files) that are alleged to promote navigation by helping users build mental models of the hyper structure via such cognitive markers. Simpson and McKnight (1990, p. 81) found that typographic cues used in a hypertext did not make navigation any easier nor did they aid readers "in forming a mental map of its structure."

McKerlie and Preece (1993) cite conflicting research suggesting the use of multiple media formats in a hyper presentation can both hinder and promote navigation. Jumping between a video node and a sound node, for instance, can increase a user's cognitive load because they are required to process incoming data from two different formats. However, people tend to remember more of what they see and hear in combination than just what they see or what they hear. The use of multiple media, then, can actually aid one in memory, and according to McKerlie and Preece (1993, p. 41), "the differences in media may act as landmarks which aid, rather than impede, navigation."

Cognitive flexibility theory suggests using "a case-based approach to accessing information" (Jonassen et al., 1992, p. 314).

Dynamic, User-Informed Navigational Methods

As noted above, Stanton and Baber (1994) cite a variety of research evidence indicating the use of maps, overview diagrams, and indexes do not adequately enable hypermedia users to access large hyper systems. Stanton and Baber (1994) suggest hypermedia authors and researchers stop placing emphasis on links to help users navigate more successfully, but instead, place emphasis on node design and the addition of descriptive features found within. The authors call for the development of object-oriented nodes that begin with no links. A type of content analysis is performed on the node with various objects in that node being classified by type, by associated keywords, and by strength of association. The difference in this navigation method versus those listed above is that it forces an author or user to place some "objective structure" on the hyper structure rather than arbitrarily assigning links (Stanton and Baber, 1994, p. 246). The resulting structure is well defined and can be easily added to once a classification scheme or system of keywords is established.

Search (1993, p. 373) describes a similar process in her HyperGlyphs project which involved the identification of "cognitive relationships between individual tasks" that were mapped to functions which help organize the hyper structure into "small, task-oriented groups of data." This process defines and organizes information into predefined categories, and users are able to casually browse or use established keywords for searching. According to Search (1993, p. 374), "permanent menus reduce the cognitive overhead for the user," and "users are less likely to feel disoriented or lost when there is a predefined path that narrows their options for navigation."

Mayes et al. (1990) describe a program called StrathTutor in which a predefined set of attributes are coded to areas of the hypertext display by an author. In this design (Mayes et al., 1990, p. 123), "fixed links are not necessary to generate [the] hypertext system." Similar to Boolean searching, learners can query the system, ask for information on combinations of the attributes, and begin to test hypotheses about which items in the hyper structure are related based on the links that are generated by their query. An important difference between this type of hyper structure based on a conceptual space and more traditional hyper structures based on a fixed space is noted, in that users are "structuring" knowledge and receiving links to explore based on their input. The users are not simply accessing information that has been "accreted" onto the structure by others. The authors fail to point out, however, that all of the attributes on which this structure is based were defined by one author, so when you look deep enough into the authoring levels, both types of systems are originated by someone other than the user.

User Tasks and Goals Supported by Hypermedia

A user may choose to access information in hypermedia to reach a variety of goals, including personal relevance, curiosity, experience, or information needs (Jonassen, 1988). McKerlie and Preece (1993, p. 36) suggest a user will perform one or more of the following tasks in an effort to meet such goals: searching (finding answers to specific questions), browsing ("gaining a sense of scope for the information"), learning (exploring and actively processing information into one's existing schemata), and organizing/synthesizing ("collecting and tailoring information").

According to Rada (1995, p. 3), users who undertake a browsing task are "dynamically building a model of the structure of the information space." Rada (1995, p. 3) distinguishes this task from searching, during which "the user has to understand something about the structure of the information space before starting and the system uses this structure to respond directly to the user's query." Rada (1995) goes on to note that the target goal of a user who is browsing is often less specific than the user who is searching. If a hyper system is structured well, however, a user might locate the required information faster by browsing, than if they were required to read an entire document. When a hyper structure approaches the network style with referential links, however, it becomes harder to browse and locate pertinent data, and reading or searching may be more appropriate.

Mayes et al. (1990) point out that user disorientation is not always a negative consequence of hyper systems. They maintain that when a goal of "structuring" information is called for, it may be good for learners to explore hyper systems, test hypotheses, and struggle with connections across the "conceptual space" as they begin to create their own mental model of the content. Similar to constructivist and exploratory movements in education, "the structuring mode of learning usually entails great effort and struggle" (Mayes et al., 1990, p. 126).

Search (1993, p. 371) encourages users of hypermedia to "acknowledge the limitations of the medium," since copyright restrictions, "lack of industry standards for exchanging information," and the high costs of computers capable of handling hypermedia have limited the medium's ability to deliver on its promise. Instead of depending solely on hypermedia as an all-encompassing learning tool, Search (1993) suggests users be encouraged to seek external resources, especially for tasks where spatial and tactile manipulation of objects is necessary to provide sensory information. It is important to note Search's remarks considering the current limitations of hypermedia. However, if access to these tools is increased and as virtual learning environments become more prominent, perhaps these cautionary remarks will become less valid.

Learner Differences

Rada (1995, p. 5) notes that "interface issues, such as button style or window placement, are often the focus of a research paper, but the biggest differences in the acceptability of a hypertext system are the characteristics of the users themselves." Ambrose (1991, p. 54) asks, "can hypermedia materials be written for large numbers of learners with diverse styles and abilities, learners who bring varying degrees of motivation?" Jih and Reeves (1992, p. 42) note at least three categories of individual differences that must be accounted for: "personalistic factors, such as knowledge and experiences; affective factors, such as motivation and attitudes; and physiological factors, such as eye-hand coordination and visual acuity." In citing hypermedia literature, Lee and Lehman (1993, p. 26) note that "insufficient attention has been paid to the role of individual differences in hypermedia program design and use."

In working with unstructured hypermedia, Jonassen (1988, p. 14) points out "the willingness" and ability of learners to use their own knowledge structures for assimilating information is dependent on individual differences (e.g., cognitive abilities and styles)." The underlying assumption in hypermedia, according to Lee and Lehman (1993, p. 25), "is that learners will actively seek out the information to form a knowledge base on a particular topic." Lee and Lehman (1993) classified a group of hypertext learners on an active to passive scale and found active subjects to spend more time on task, view nodes with elaborative information more frequently, and perform better on achievement measures. Those students who were classified as passive required instructional cues such as "hints to view embedded information" to respond to the hypertext in such a fashion (Lee & Lehman, 1993, p. 25). Active learners performed well regardless of instructional cueing. Assuming all learners will use hyper links because they are there is not a valid assumption.

In addition to Lee and Lehman's (1993) active/passive continuum, Jih and Reeves (1992) note learners may either be field-dependent (more successful when support and computer-driven designs are offered) or field-independent (more successful at exploratory activities and capable of independently testing hypotheses and structuring concepts). Other terms for this same apportionment include external locus of control (passive, dependent learners) versus internal locus of control (active, independent learners) (see Pintrich & Schunk, 1996). External, passive learners tend to be extrinsically motivated while internal, active learners are more intrinsically motivated.

In a study of learning styles in non-linear environments, Stanton and Stammers (1990) classified learners into three categories: those that viewed information in a top-down format (looking for the most important information first), those that viewed information in a bottom-up format (starting with basic information and progressing to more integrated concepts), and those that viewed information sequentially. Stanton and Stammers (1990) show time on task is less for top-down learners who access fewer nodes and appeared able to integrate information more easily based on a mental model structure that was developed prior to the study. The bottom-up learners were more field-dependent than the other groups, however, and appeared to "fill-in" a new mental model as they obtained experience with the information (Stanton and Stammers, 1990, p. 118). Stanton and Stammers (1990, p. 119) note "we should not be too rigid in our thinking about styles," because dependent upon the task a user is given, they are likely to adopt differing styles in response to differing situational demands.

The degree to which learners can handle the freedoms brought about in hypermedia is somewhat based on the goals they bring to the learning environment. In their study of the StrathTutor hyper system based on a conceptual metaphor, Mayes et al. (1990, p. 127) point out that "subjects either learn to navigate in the hypertext or they learn the instructional material, but...they cannot do both together." This would suggest that some users have or develop a product orientation to doing well in hypermedia by learning the instructional content, while other users either have or develop a process orientation to the task by struggling with and failing to automatize the task of navigating through the hyper system. These orientations are obviously more complicated than an either/or classification, and are interconnected with a learner's curiosity, motivation, self-regulatory strategies, and more.

Kinzie (1990, p. 62) cautions that "availability of [hypermedia] is not enough to ensure...learning." The technology is a tool that can facilitate learning, but we must first consider a variety of learner factors such as learner control, self-regulated learning, and motivation (Kinzie, 1990). We can not assume all individuals will necessarily or equally take advantage of the tools they are provided.

Rada (1995, p. 5) notes the large effect of user age on attractiveness of using hypermedia,

Young users found hypertext to be attractive, whereas middle-age users were disinclined to use hypertext.

Further, according to Rada (1995, p. 5), those users who were motivated to perform a task "contributed much more to the hypertext exercise than did those whose motivation was less."

Can learner differences be taken advantage of? Repman, Weller, and Lan (1993) note that considerable research has been conducted on individuals using hypertext systems, but few studies examine the impact of collaborative efforts in hypermedia. In settings where collaboration is encouraged, students can provide one another with mutual guidance, support, and encouragement (Repman et al., 1993). When "disagreement over conclusions and tactics" is encountered, this too can be beneficial as students verbalize their opinions which helps them to learn by elaborating on the content, and also, reconcile their differences which helps to build social skills (Repman et al, 1993, p. 286). Repman et al. (1993) designed a study to measure the impact of grouping learners of differing capabilities together while using hypermedia. The results suggest low ability students can benefit from a heterogeneous grouping with high ability students, but that high ability students might achieve less when heterogeneously grouped with the lower ability students. The authors suggest the use of built-in collaboration with programmed guides or intelligent agents might be another form of collaboration with an "intellectual partner."

Learner Control

Learner control through hypermedia can take three basic forms: total control for the learner, partial control with guidance from the system, or programmed control in which the learner gives up all control to the system as designed. Jacques et al. (1993, p. 221) point out that "authors of hyper-systems believe they can encourage active learning by providing information which students can configure to suit their own particular needs," but even if "educational materials are designed to promote active learning, students often need support to take advantage of the opportunities offered." Marchionini (1988, p. 10) points out that "distraction is due to the high level of learner control" offered by hypermedia systems, and further, "freedom can be confusing because it increases decision-making load." So, what is the proper form and level of learner control in hypermedia systems?

Learner control in hypermedia is beginning to take on new forms. Users are no longer limited to freely accessing someone else's hyper structure, but increasingly, they can begin to "add or subtract materials and can create new links among the components" (Ambrose, 1991, p. 52) (see also Dynamic, User-Informed Navigational Methods earlier in this paper). McKerlie and Preece (1993, p. 41) suggest users have three types of "control over structure," including passive control where only link decisions are made, some control where link-node traversals can be saved, and more radical control where the user takes on an "authoring role" and can begin to "influence the link structure by adding or removing their own links between nodes."

In addition to "control over structure," McKerlie and Preece (1993) indicate at least two other types of control can be provided to users of hypermedia. First, control over media where a user can vary the speed and direction of time-dependent media such as video and sound, and second, "control over the work environment" where additional tools such as word processors, drawing tablets, and note pads, are provided to the user for elaborating on the hyper structure.

When users are given control, how might they react? Horney (1993) designed a qualitative study to measure the linearity or nonlinearity of eight users' navigational patterns through hypermedia stacks they designed with an authoring program. Conclusions of the study were: different people approach and link through hypermedia documents differently (see Considering the Learner earlier in this paper), and just because a hypertext document is structured with multiple links does not mean individuals will make use of all of them. Horney points out that nonlinearity should not be studied as a function of hypermedia, but rather, as a function of certain users.

In a study of hypertext use, Becker and Dwyer (1994) demonstrated learners using hypertext felt more self-determined through a perception of increased control than learners using text-based materials. These learners were also shown to have higher levels of intrinsic motivation. The authors point out, however, learners must actually perceive more control over their environment to have increased motivation, and this perception can be hindered when the learner is first beginning to use a complicated or unfamiliar hypertext structure. Kinzie (1990, p. 63) discusses similar potential benefits of increased learner control via hypermedia:

> When learner control is exercised, benefits can be measured in terms of increased student self-regulation and continuing motivation.

As Kinzie (1990) points out, providing learner control can motivate some students and provide them with the opportunity to practice self-regulatory, learning strategies. In terms of self-regulation, however, Marchionini (1988, p. 12) suggests caution,

> The privilege of freedom demands responsibility; the responsibilities of using hyperdocuments include knowing when and how to stay oriented and attentive to goals.

Caution should be exercised in assuming the opportunity to learn self-regulatory strategies will always be beneficial and that all users are equally capable of handling the increased freedom. Jacobson and Spiro (1995, p. 305) note, "no studies have been reported that explore epistemic cognition within the context of using a hypertext learning environment." Epistemic cognition reflects an individual's belief system "related to the acquisition and structure of knowledge," (Jacobson & Spiro, 1995, p. 305) and effect one's behavior toward solving problems.

Self efficacy is a motivational construct stemming from the confidence learners feel in approaching and handling new tasks such as hypermedia learning environments. According to Bandura (1993), self efficacy can be significantly lowered when students are told by instructors they have the skills to succeed on a task (e.g., working in hypermedia environments), they continue to try hard, yet fail (e.g., become disoriented, lost, confused in the hyper structure). In these instances, students begin to attribute their failures to their innate abilities and might make statements such as, "I've always been lousy with computers, and there is no way I'll ever figure out this hyper program." In fact, older students tend to view their ability level as relatively stable and unchanging (Dweck & Leggett, 1988), so this potential outcome is magnified in educational settings beyond middle school.

When students are provided with learner control in hypermedia, it is necessary to ensure each has a realistically defined sense of confidence to succeed, as student attributions can subsequently effect student goals taken toward a task (Dweck & Leggett, 1988) as well as their motivation and curiosity (Weiner, 1994). Students who feel they lack the ability to succeed tend to undertake a performance orientation toward tasks with a goal of failure avoidance. These students are typically motivated extrinsically and engage the task as a "means to an end" (Pintrich & Schunk, 1996, p. 258). Intellectual curiosity suffers as students fail to seek out external classroom resources and have little interest in elaborating on classroom content. Conversely, students having problems with a task who attribute them to lack of effort are more likely to undertake a mastery orientation and adopt goals of improvement and learning. These students are more likely to be intrinsically motivated and work hard to learn.

According to Kinzie (1990, p. 66), "individuals who possess effective self management strategies and who are willing to use them, will be the most effective users." Kinzie (1990, p. 64) further mentions,

> Until users become familiar with the use of hypermedia-based learning systems, it may be necessary to explain how they function and to provide students with structured experience in their use.

Kinzie (1990) then suggests before users be allowed to browse a hyper structure, they should be given an overview of the system. Within the overview and throughout the system, students should be prompted to use various learning strategies employed by the program in such following ways: ".... check the dictionary for a definition," "don't forget to use the note pad," "you might want to diagram the social structure....," "remember you can use the map to find out where you are...." (Kinzie, 1990, p. 65). Use of hints and prompts in a hyper program can help to ensure successful learner control for those students lacking self-regulation skills.

Nielsen (1995) suggests hypermedia holds more promise than artificial intelligence or expert systems, because it ideally involves the user, in some form of control, making update and customization decisions, and adding links. The hyper space, then, becomes what the user makes of it, aiding him or her in personally relevant construction of knowledge. These types of interactive activities become more valuable for the learner than passively receiving information already collected and organized by an "expert." Realistically, however, control can not always be given over to the student, and certainly there are instances when a more program-controlled design is called for. Hypermedia authors must choose the appropriate level of control for their systems based on an analysis of the tasks or information they are hoping to teach or convey.

Virtual Learning Environments

Despite the development of theory and a great deal of research on hypermedia, few studies have examined the impact of learning environments that are virtual in nature. Virtual environments allow learners to engage in surrogate travels or experiences when "being there" or "doing it" is not possible, safe, or practical. Virtual environments can be thought of as realistic representations of actual objects, people, places, and events. Examples of virtual environments include virtual reality applications and 3-dimensional games using rooms, levels, and imaginary spaces that can be roamed and explored. According to Wickens and Baker (1995), space is the key metaphor of virtual environments--the ability to enter a space, and to varying degrees, interact within it.

A discussion of virtual learning environments (VLE) is included in this literature review of hypermedia, because these environments are typically "hyper" in structure. Links and nodes are not as obvious in these environments, but the idea of a user navigating through a learning space is still the same. Obvious differences exist, however, in that VLE are apparently more intuitive, realistic, and conceptually-based than more traditional hyper systems. As more and more virtual designs are incorporated into multimedia products and onto the internet, there appear to be several potential benefits to using these hybridized hyper designs. Design guidelines from an existing body of virtual reality research will need to be followed, however, and future research conducted to study the impact of VLE on learners and the educational system.

Characteristics of Virtual Learning Environments

VLE can be totally immersive with head-mounted displays that change the visible scene based on a user's head movements and data gloves and clothing that are capable of constriction as a user "touches" various items in the virtual space. These systems are typically referred to as virtual reality. More common, however, are new forms of VLE that are nested within a multimedia product or on the internet, and viewed on a computer screen. These VLE are known by many names such as virtual worlds, metaworlds, and the metaverse (Rossney, 1996). While these environments that run on the home or school computer do not require the extremely expensive equipment and computerized clothing of virtual reality systems, they give up some degree of immersion in the environment while saving on overall cost. Some common virtual environments that are currently accessed via an internet connection include: Fujitsu's WorldsAway, Microsoft's V-Chat, Worlds Inc.'s AlphaWorld, and Time Warner's Palace (Rossney, 1996). Note that these environments were described as "virtual" but not with the descriptor "learning," since they are largely for entertainment value. Virtual environments have great potential to influence education, but few systems exist in this capacity--perhaps one reason for the lack of research in this area.

Regardless of the system that delivers the VLE, Wickens and Baker (1995, pp. 514-515) point out they have five features in common: "three-dimensional viewing"; dynamic, changing displays; interactive, learner-centered action; some frame of reference (i.e., viewing the scene from a first-person point of view versus an overriding, global point of view); and, "multimodal interaction," or a variety of user inputs such as the computer mouse, a data glove, and speech recognition. Depending on what the system is being used for, these different features can be incorporated for overall effect, or left out to save on cost (Wickens and Baker, 1995).

Rossney (1996) describes three common features of VLE: avatars, gesturing, and persistence. VLE employ "avatars" or simulated beings that represent our presence in the environment. A user interacts with the VLE by moving the avatar around the space, picking up objects, and gesturing to other users in the space.

Potential Benefits

The emergence of virtual worlds has the potential to enhance hypermedia systems in several ways: providing a more realistic, user-friendly, contextual-based metaphor for navigation; better opportunities for knowledge construction; and better opportunities for knowledge transfer.

New Metaphors for Navigation

Claims have been made that hypermedia helps students learn new content, because it matches the semantic structure of our minds. This is despite the fact that most hypermedia information is currently designed and structured to represent an author or expert's view of the content. Locatis et al. (1989, p. 72) note,

> ...links can be made in many ways, even quite arbitrary ones, that, although practical, may have little semblance to how people associate content. ...Since more meaningful linking is

> more likely to resemble the associations of authors (and presumably experts), subjects may be structured in ways that fail to account for differences in expert and novice knowledge representations.

Instead of following author-constructed links that often neglect representations of the learner, VLE allow a learner to interact in a world that is familiar and representative of real-world mental models they possess--references such as books, articles, and magazines can be selected off virtual bookshelves; an expert opinion can be elicited by navigating the virtual space to that expert's room and knocking on the virtual door; a phone call is placed by picking up the virtual phone. This is not to say a user is incapable of learning how to use a traditional hypermedia system with text and graphical links, however, it is possible that a more realistic interface might make these tasks more transparent, freeing up valuable cognitive space for a learner to focus on content and not on navigation.

Metaphors for navigating virtually include the avatars discussed previously. It should be noted, however, that while this method of navigation is more representative of the real-world (manipulating a walking, talking, being as opposed to a computerized pointer tool), it is possibly more difficult to master than text and graphical links found in traditional hypermedia. In navigating through virtual space as a "being," users have many more options than navigating through a traditional hyper space by pointing and clicking the mouse. The user, for instance, can gesture to other avatars in the space (e.g., wink, wave, crouch), talk to other beings encountered (e.g., "Hi, I'm Bob, and I'm looking for information on the French Revolution."), express emotions (e.g., cry, smile, pout, stare), and choose to walk, run, fly, drive a car, etc. This type of interaction can arguably lead learners to more quality information and allow them to construct knowledge for themselves more fully by discussing it with others, but will this overwhelming array of new navigation options confuse learners more than ever before? Negroponte (1995) suggests further advancement in technology might be needed that will make some of the unspoken language requirements more transparent. For instance, developing computers that can read our expressions and gestures and send that information to the avatar representing us in virtual space might free up cognitive space for a learner to focus more on seeking, evaluating, and comparing information.

Better Opportunities for Knowledge Construction

Dede (1992, p. 56) sees the future of hypermedia as one that evolves "beyond knowledge representation to knowledge construction, so that the learner can modify/add nodes and links." The type of knowledge construction Dede describes here seems representative of the non-virtual, hypermedia environment in terms of "nodes" and "links," yet few non-virtual databases (including the World Wide Web as it exists today), allow for the manipulation of nodes and links as constructed by the original author. Rossney's (1996) review of metaworlds, on the other hand, clearly point to environments in existence today that allow for "persistence." That is, the user can build a home in the space, collect objects, collaboratively build up an economy with other avatars, and after logging off and back onto the system, the work remains in place, dynamically changing, and in a constant state of flux dependent upon user input and construction. VLE improve upon less-interactive models by allowing for the user to actively participate in the structuring of the space.

DeLanda (1994) poses an analogy for the construction of artificial life via computer environments by comparing it to natural selection and genetic inheritance. According to DeLanda, (1994, p. 264) the "ideal type" as proposed in "population thinking" should be downplayed in favor of more emergent designs as nature dictates. The role of a hypermedia author, then, is simply to set up an empty world and let nature take its course, let behaviors emerge. As DeLanda (1994, p. 269) notes,

> What virtual environments provide is a tool to replace (or rather, complement) analysis with synthesis, to deal directly with populations of entities in nonlinear interaction.

DeLanda (1994, p. 269) further downplays the idea of artificial intelligence (AI) as an analytical approach that "dissects a population into its components." More favorable, is the "connectionism" movement that does not sacrifice the connection between a learner and their personal sense of the world like the "top-down, symbolic approaches of AI" (DeLanda, p. 272). DeLanda (1994, p. 276) further describes this trend as "nonlinear dynamics" and points out that an attempt to reduce complex interactions to lower levels is not possible, because properties that emerge out of these interactions will disappear when studied in isolation. What learners in VLE construct, then, is their personal world--one that would not exist or would exist in a different way were it not for the input and collaborative effort of its "inhabitants."

DeLanda's (1994) reasoning provides a transition between the idea of constructed knowledge to the next potential benefit of VLE--flexibility and transfer, for VLE are truly representative of flexibility theory. They can be designed to allow learners to use information and knowledge in situations that change daily based on the nonlinear, dynamic, changing environment--tasks which will surely lead to better transfer over the more canned approaches of instructional design that "chunk" knowledge into their "ideal type."

Contextual Transfer

According to cognitive flexibility theory and Dede (1992, p. 56), "learning situated in virtual worlds similar to the real-world setting in which knowledge and skills will be applied is more likely to transfer." Virtual worlds can be designed to represent any number of real-world settings from the common flight simulator to anthropological field studies where students can learn how to interact with differing cultures and not insult the indigenous people. If cognitive flexibility theory holds true, then learning situated around such authentic, case-based scenarios will transfer to the real world as students are required to use knowledge and apply strategies in different settings. The knowledge will become more flexible and capable of use in multiple situations.

Virtual Learning Environment Design Implications

VLE have many potential benefits revolving around their ability to provide authentic, context-based experiences, design issues, according to Dede (1992, p. 57), must be taken into consideration:

> Just as current instructional systems must match a mixture of textual, auditory, visual, and psychomotor presentations to the student's learning style, so virtual worlds that use visualization must balance representations of physical objects, sensory transducers, and cognitive transducers.

Sensory transducers are one type of visualization allowing learners to perceive the imperceptible (e.g., molecules, atoms), while cognitive transducers transform symbolic, intangible concepts into geometric form for better comprehension (Dede, 1992). Dede points out the need to examine virtual worlds in terms of their design in order to use visualization techniques appropriately.

Wickens and Baker (1995, p. 518) note several tasks users may be expected to perform when interacting with VLE: searching, navigating, perceiving, and manipulating/interacting. Each task has associated design requirements.

In order to support visual searching in a virtual environment, maps can be used, but they should be uncluttered, flexible and changing as the user moves through the space, and linked so as to allow branching or jumping to various locations in the space (Wickens and Baker, 1995).

Navigation techniques that employ real-world metaphors such as bicycles and cars can be used, but in order to maintain their realistic notion, their speed in transferring the user around will need to remain considerably slower than faster, point-to-point navigation structures (Wickens and Baker, 1995). While point-to-point navigation is faster, it drops a user off at a point in the space that might be unfamiliar and disorienting, because they did not arrive at that location by way of the surrounding terrain (Wickens and Baker, 1995).

Perception is a key consideration in the design of VLE. Frame of reference is one perceptual concept that must be developed. Will the user view the scene from a first-person point of view or from a second-person point of view? Wickens and Baker (1995, p. 523) point out that the second-person, exocentric view can distort the perception of "other objects' locations and the perception of one's own location." Visual design is another perceptual consideration for VLE design. VLE designers must ensure "regularly spaced texture, and level surfaces" are used in the display, "to support the accurate perception of gradients, slant, and optic flow" (Wickens and Baker, 1995, p. 522). In order to maintain the perception of realism, systems should be employed with minimal time delays that cause lag in the screen display when moving. Further, two distinct types of movement may be required to maintain the perception of realism--one of motion (simply moving from space to space) and another of velocity (moving from space to space, but in an accelerated or decelerated fashion) (Wickens and Baker, 1995). According to Wickens and Baker (1995, p. 525), VLE that employ "travel-view decoupling" (e.g., being able to "look" from side to side as one travels through the space) will seem more "natural" to the learners.

VLE designers must also consider how users will manipulate objects and interact with the environment. What are the movements, gestures, communication capabilities, and emotions that the avatars will be allowed to express?

Virtual learning environments might look to related learning tools already in use (e.g., microworlds) to help inform their design. Microworlds designed as Rieber (1992, p. 103) suggests "give users exploratory experiences within a carefully controlled range of concepts and principles...." Microworlds are "artificial realities" through which a learner can vary elements of a simple model and subsequently examine the results or receive specific feedback related to their input (Dede, 1987, p. 23). They are typically limited in scope and involve alteration of a model to study the changes and effects brought on by interacting variables. An example of a microworld is described by Rieber (1992) who used a 2-dimensional, line-art drawing of a space shuttle in a computer program. Students learning about Newton's laws of motion used a computer mouse to click on the space shuttle a certain number of times to give it thrust and make it move.

Microworlds and virtual worlds are similar in purpose and typically refer to similar design guidelines. Virtual worlds are not necessarily designed for alteration, however, and are frequently of a larger scale than their limited microworld cousins. Microworlds, on the other hand, are not necessarily designed to be virtual, realistic, and 3-dimensional, but they can be on a much smaller scale. When alteration of a model is involved on a large scale (e.g., an entire house or building to be altered versus a single room or level), this type of learning environment can either be thought of as a macroworld, or if realistic enough, a virtual world.

Rieber (1992) suggests microworlds offer a compromise between inflexible, direct instruction and constructivism which might be too loose when minimal instructional direction is offered. It is suggested here that virtual learning environments might also be designed the bridge the gap between these two modes of instruction. According to Rieber (1992, p. 95), microworlds embody "the simplest model of a domain that is deemed accurate and appropriate by an expert," and they offer "an initial point of entry which matches the user's cognitive state so as to allow fruitful interaction to take place." Rieber's (1992) study combined an instructional tutorial introducing

Newton's laws of motion with an exploratory activity allowing the students to construct their own mental model of the data. While the simulation/exploratory portion of the computer program represents the actual microworld, the deductive tutorial when united with the discovery world adds an element of validation to the study and promotes accountability that learning goals are being met. Rieber (1992, p. 101) notes, "novices often need structure or guidance which purely inductive experiences do not provide, a problem frequently encountered by designers of hypertext." It is not unlikely to believe that users of virtual learning environments might also need such guidance.

Future Areas of Research

Potential benefits of VLE were described earlier, but few studies exist that examine the real impact of VLE on education.

Realistic metaphors for navigation might make interacting in hyper structures more intuitive. Still, few studies have investigated the influences on education of manipulation and interaction in hypermedia with contextual, authentic interfaces. Gygi (1990, p. 286) recommends caution in employing this new navigation strategy haphazardly,

> Although humans have highly developed visual and aural perceptual skills, it is not clear that our abilities to understand and manipulate non-text-based representations are similarly well developed. At a low level, there is the problem of ambiguity, pictorial and perceptual, in graphical interfaces.

In terms of using avatars as a new form of interaction, one can imagine the difficulties which will certainly be encountered as hypermedia developers begin to design and program simulated beings. Developers of these environments not only must deal with traditional design issues, but also with designing personality traits, physical traits, attitudes, and emotions. How to effectively design such environments and their implications on learning and development represent vast areas of research for the undertaking. It is quite possible, however, that the designers of the future won't be software developers, but rather, the users themselves who choose the personality traits and attitudes reflecting their own as they become an avatar and interact in a virtual world. If this is the case, what are the implications for this new type of learner control? Should users interact in a world as themselves or experiment with a variety of different roles?

In his study of interactive fiction, Nielsen (1990) discovered students accessed most of a story in a first-person style by clicking on objects or locations to which they wanted a character to go. As students got into the program, however, the navigational metaphor switched to second-person where the students were required to click on the character to make it move, not the objects. This inconsistency seemed to cause some confusion among users who kept trying to click on objects and not the character itself. Designers of virtual worlds must take into consideration the need for consistency across first-person, second-person metaphors, as well as educational implications for what exploring the virtual world in each of these roles teaches.

In terms of constructed knowledge, which is more likely to emerge from the use of VLE in education: an emergent, constructed, "synthetic reasoning" as DeLanda (1994, p. 284) suggests that helps to describe and track the stabilizing forces and diversification of society; or, an artificial reality that serves to keep individuals isolated behind their computer screens and disattached from the "real" world?

Finally, related to the design of VLE to promote transfer of knowledge to other learning situations, environments need to be developed and studied in relation to cognitive flexibility theory, as the theory has several tenets that seem to support the use of VLE. What effect does the provision of multiple representations have on learning (e.g., a student can play the role of any number of avatars and study differing perspectives)? What types of case-based instruction can be implemented? Does the placement of knowledge in a virtual setting enhance learning over more traditional approaches? How do students exercise control in such settings--by exploring the worlds in self-defined paths and developing their own mental models, or in chaotic, random fashion? Can design models be borrowed from other tools such as microworlds to ensure the former rather than the latter? And, finally, how can VLE best support the complexity of knowledge--by allowing students to switch back and forth between cases, comparing and contrasting, or by considering implications of differing representations and points of view?

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