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ABSTRACT

This monograph provides a conceptual and theoretical framework for the use of hypermedia presentations in the classroom, particularly in the science classroom. Traditional methods of presenting information are linear in nature but research has shown that learning rarely proceeds in a linear fashion. The omni-directional nature of hypermedia presentations has fit quite nicely into the models of learning of some of the most recent cognitive theories. They have been particularly well suited to several important needs for science education. These topics are discussed in relation to some ongoing research projects. (Author/PR)

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Hypermedia:

A Conceptual Framework for Science Education and Review of Recent Findings

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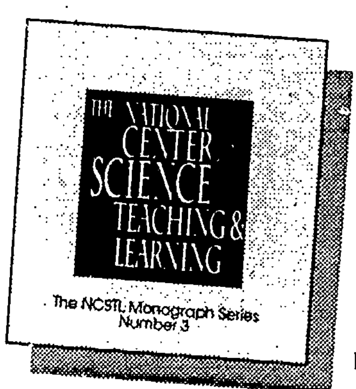
Hypermedia: A Conceptual Framework for Science Education and Review of Recent Findings

E. Jean Marsh & David D. Kumar

Here-in, an attempt has been made to provide a conceptual and theoretical framework for the use of hypermedia presentations in the classroom, particularly in the science classroom. Traditional methods of presenting information were linear in nature but research has shown that learning rarely proceeds in a linear fashion. The omni-directional nature of hypermedia presentations have fit quite nicely into the models of learning of some of the most recent cognitive theories. They have been particularly well suited to several important needs for science education. These topics are discussed in relation to some ongoing research projects at Vanderbilt University.

Introduction: What Is Hypermedia?

In order to understand the concepts of hypertext and hypermedia, it may be helpful to consider the analogy to printed documents presented by K.E. Smith (1988). Authors often use footnotes, endnotes, sidebars, and bibliographies to refer their readers to related materials and to incorporate additional information that has a bearing on their article or topic. This idea of linking information that is related is the basis for hypertext and hypermedia systems. In a sense, it is nothing new, because authors of printed literature have been doing it for years. Anyone who has read an article in an encyclopedia is familiar with the list of related topics at the end, and has tried at one time or another to trace a theme through a series of footnotes, endnotes, and external sources.



What is new about hypermedia is that it is an attempt to provide a method of linking information and concepts without requiring the user to physically leave the environment in which he is working in order to follow those links. It is designed using computer software which allows the author to create a network of interconnected electronic cards, or screens, in such a way that they represent a collection of related ideas, and organize, store, and retrieve information (Halasz, Moran, & Trigg, 1987). Each screen is thought of as a notecard or page, and instead of sidebars and footnotes, the user is provided with buttons that allow him to branch to related ideas, information, and concepts. This link might take him to another card with additional printed information, to an audio recording, or to a video segment that is received on a TV monitor hooked to the microcomputer and to a videodisc player. So a hypermedia presentation can be a multimedia presentation in that it has the potential to utilize many methods of presentation, and it is omni- directional in that a well designed presentation allows the user to branch in many directions depending on his needs and interests.

Although commercially available software packages that enable one to create hypermedia presentations are relatively recent, some of the concepts have been around for quite awhile. In 1945, Vannevar Bush, President Roosevelt's Science Advisor, wrote an article in the *Atlantic* in which he described a tool that would allow people to access a large collection of microfilm and would provide certain mechanisms that would make links between any two pieces of information (cited in Tsai, 1988). At that time the technology did not exist to develop such a device; "nonetheless, today's hypertext literature credits Bush as the first to think of using a machine to store connections between pieces of information" (Smith, 1988, p. 33).

Although Bush's article dealt with the creation of a device for linking information, the main thrust of the article dealt with two things: the explosion of information that he saw resulting from technological developments, and the way in which people learned or formed mental representations of knowledge. This is important, because it was not the technology that was important in the Bush article, but rather that he recognized the fact that the sheer amount of information becoming available demanded that people have the ability to access information in new and innovative ways. Additionally, he suggested people should be able to access information in a way that better mirrored the way they think. He argued that people do not think in a linear fashion, but rather by forming omni-directional associations, or links (Tsai, pp. 3-4). It is the inclusion of these two concepts that distinguishes hypermedia presentations from electronic data bases. Information is presented in small segments, usually in the form of *notecards* or *pages*, but the sequencing of these segments is not forced into the linear representation dictated by the constraints of the printed page. The users may follow their own inclination as to the sequencing and branching they wish to pursue. By simply clicking on a button on the computer screen, by means of a computer mouse, the user may branch to supplementary information, or related concepts or explanations as the need is felt.

> *"So a hypermedia presentation can be a multimedia presentation . . . "*

Today there are several commercially available software packages which allow users to create their own hierarchically structured entries and to link these entries with other segments, video clips, sound tracks, or graphic displays. Probably the best known of these packages is *HyperCard*, developed by the Apple Computer Company. Also available is *Intermedia* developed by Brown University, *Linkway* from the IBM Corporation, and *Toolbox* from Asymetrix.

Some Cognitive Theories of Learning and Hypermedia

Hypermedia has generated considerable interest in the educational world in recent years. This is directly attributable to the fact that it presents a very convenient way of representing knowledge structures congruent with some of the current learning theories. Several cognitive theorists, along with some psycholinguists, have developed a conception of learning that uses models of the structure of knowledge that can be adapted to the hypermedia milieu.

In the early 1970s investigators of human memory began to theorize about distinctions between various types of memory. One of these distinctions is between episodic memory and semantic memory. According to Bower and Hilgard (1981), episodic memory deals specifically with the kinds of memory that have a definite time frame, includes sensory attributes, and has an autobiographical reference. For instance, people may remember exactly what they were doing at the time they heard of the assassination of John F. Kennedy. Semantic memory, on the other hand, has no autobiographical reference; we do not remember how or when we learned an item of information, but it is considered part of our permanent knowledge (p. 444).

Of particular interest to this paper are the ways in which knowledge is represented and organized in semantic memory. According to Bower and Hilgard (1981), "There are currently two major methods for representing semantic knowledge, both of which are exemplified in current computer simulation programs" (p. 449). The first of these methods represents knowledge in a graphic model with points, or nodes, which represent concepts and links which are seen as semantic relationships between the concepts. The second method attempts to represent concepts "in terms of inference rules (productions) and decision routines....Knowledge is represented generally in terms of action recipes or procedures for how to bring about some consequence or make some decision" (Bower and Hilgard, p. 449).

If one takes the first view, then learning is seen as a reorganization of the knowledge structures in semantic memory. These knowledge structures refer to the organization of ideas, or schema, in semantic memory. Each of the schema is comprised of a set of attributes, or associations that an individual forms around a concept or idea. These schema are seen as frameworks around which attributes or associations about a topic are organized into concepts. These concepts are in turn arranged into an interrelated series of concepts called a semantic web, or semantic network. As Jonassen (1988) has noted,

> *Following from this description of semantic networks, learning consists of building new structures by constructing new nodes and interrelating them with existing nodes and with each other. The more links that can be formed between existing knowledge and new knowledge, the better the information will be comprehended and the easier learning will be. Learning is conceived of as a reorganization of the learner's knowledge structure (p. 13).*

In a report entitled *Studies in learning and self contained educational systems* written for the Office of Naval Research (1976), Norman stated that, "In order to be able to develop good tutorial teaching systems, we need to be able to (a) represent subject matter knowledge and (b) model its structure, including knowledge representation, in a way that will (c) provide principles and strategies of instruction" (cited in Jonassen, 1986, p. 274). In other words, cognitive models of teaching must derive from cognitive models of learning. Hypertext and hypermedia are seen as having great potential because they offer a convenient way to represent subject matter knowledge and model the structure of knowledge. If learning occurs when new knowledge is integrated into a preexisting web of knowledge, then it stands to reason that teaching should incorporate this concept in presentation of new material. Accordingly, material should be presented in a web like fashion, with information necessary to form the framework presented first, and supporting details presented later (Jonassen, 1986). However, to be in full accordance with web learning principles, it is also necessary to assess the learner's knowledge base in order to ascertain the existing framework of knowledge so that materials can be presented in a way that would link them to the preexisting knowledge base. This can be done in hypertext by structuring the content in a knowledge web, determining the network of information possessed by the student, and matching the two. This can be done effectively only on a computer system at the present time.

A slightly different learning theory which is also amenable to the use of hypertext is the generative learning hypothesis. These two views of learning are similar, but the major difference is that the generative learning theory stresses that the learner creates (or generates) meaning for himself. "According to the generative model of learning, learning is an active process of constructing knowledge. Meaning for text is learner controlled (conceptually driven) rather than text controlled. What individuals comprehend from material depends on what they already know" (Jonassen, 1986, p. 278). One of the interesting corollaries to this theory is that there is no ideal sequence forthe presentation of content; the unique knowledge base of the individual determines what sequence is ideal for him. This need for individual control of the sequence of accession is what makes hypermedia ideally suited to this model of learning. "Hypertext permits learners to individualize the knowledge acquisition process. Hypertext allows them to interact with new information in the way that is most meaningful to them" (Jonassen, 1986, p. 278). This may have particular significance for science education.

". . . concepts are in turn arranged into an interrelated series of concepts called a semantic web . . ."

Potential Applications in Science Education

Although the possible applications of hypermedia in science education have not yet been fully explored, the potential for making science more meaningful to the learner seems to exist (Marchionini, 1988). Seyer (1989) has characterized a hypermedia application as a spatial environment for building systems designed for information management and representation by extending beyond two dimensional perceptions. It is this ability to organize and manipulate irregularly structured information that seems to make hypermedia applications ideally suited for a variety of scientific applications ranging from classroom science instruction to engineering. Following is a discussion of some of the ways that this new technology might be useful in science education. Included are three major areas in which it might be found to be useful: (a) the ways in which information is physically delivered, (b) theoretical concerns of curriculum design, and (c) promoting scientific investigation and inquiry among students.

Physical Delivery of Information

It is possible to design hypermedia applications which can be used as electronic libraries (Miller, 1988), and in fact Nelson (1981) suggested that the technology could be used as a tool for storing and distributing the world's entire scientific and literary information. This aspect of hypermedia could add a new dimension to the traditional classroom environment by placing almost limitless amounts of information at the fingertips of the learner.

The development of interconnected data bases would allow users to take full advantage of the capabilities of hypermedia for linking these data bases in such a way as to emulate a large electronic library. There are many advantages to the use of a hypermedia application as a library system, some of which are described by Conklin (1987) and Shasha (1986). For one thing, as was discussed previously, hypermedia applications provide an easy way of tracing references because all references are equally accessible and can be followed either forward to the referent, or backward to a previous reference. In addition, it is possible for learners to construct their own information networks. It is possible to impose either hierarchical or non hierarchical organizations on unstructured information, and text segments can be threaded together in different ways, allowing the same document to serve multiple purposes. The linking capabilities of hypermedia applications provide the ability to access, or reference, the same text segment from several different nodes, or locations. This tends to cut down the amount of overlap and duplication of information within the text. Finally, there is more consistency for the user, because the information presented is linked directly to the original concept even though the links may thread their way through several different topics as the users follow the references in which they are interested.

An example of how this might work in a science classroom might center on the teaching of chemical concepts which require background knowledge. Using a hypermedia application set up to link several interconnected data bases, a student would be able to trace both the meaning and definition of the concepts under investigation. This would increase the flexibility and obviate the need for rote memorization. Furthermore, in addition to both definitions and meanings, the well documented hypermedia system would allow the learner to access any information related to the topic under investigation and extend the investigation in any direction.

Not only could hypermedia applications provide students with an almost limitless electronic library, but they could also be used to replace traditional textbooks with more student-centered computer textbooks. Vandergrift (1988) predicts that this change will occur because hypermedia is a non-traditional delivery of many forms of informational and aesthetic contents available to a computer user with the click of a mouse. Such applications enable readers to unlock a book, ask questions, and explore any information at their own convenience. Textbook publishers are already finding ways to fully utilize hypermedia technology for presenting text materials with more flexibility than ever before possible (Tchudi, 1988). In addition, the interactive role of graphics linked with text materials can be fully utilized using a hypermedia application.

"... hypermedia could add a new dimension to the traditional classroom environment..."

As a specific example, it would be possible to use hypermedia to arrange graphic representations of atoms in such a way as to give the learner access to visual examples of every particular detail of the electronic configuration of atoms. By clicking on the icon for a particular atom, the learner could branch to a graphic representation, find answers to questions, and even make quick cross references. It is even possible to include links to interactive videos of simulations showing how electrons are placed around the nucleus in the order of increasing energy and decreasing stability. Traditional methods of presenting the same information require the learner to make time consuming manual searches of cross referenced material in order to make the links which enable them to accommodate the information into their own cognitive structure.

Chemistry professor Melvin D. Joesten of Vanderbilt University created such an application for use with his chemistry students. Working together with programmer John Harwood, he produced a *HyperCard* application that linked video clips from a videocassette series, "Program 7: The Periodic Table," produced by the University of Maryland and the Educational Film Center. To do this it was necessary first, with permission from the film's producers, to prepare a videodisc version of the desired film sequences. Then, working with the programmer, the stacks linking the video clips were created. The completed program deals with the topic of the periodicity of the elements. The user of the stack can access video segments detailing biographical information about Mendeleev, an animated sequence depicting his prediction of the missing elements, and graphics showing atomic size and its relation to periodicity. In addition students can see manufacturing applications of the concepts, interviews with key thinkers in the field, and even a demonstration in which a football team in a sports arena models how the electron orbitals fill up. All these concepts are linked together with a very few cards in the stack. The student can branch in any direction that suits his immediate purpose. The provision of such aids to learning are becoming more commonplace on campuses across the country.

Curriculum Design

The physical delivery of information may not be the only way in which hypermedia applications affect the curriculum in the future. Certain features of hypermedia applications may enable curriculum designers to address theoretical concerns as well. One area of recent theoretical concern has been the individualization of learning, or the degree to which learning can be adapted to meet the needs of the individual. Marchionini (1988) has characterized the learning environment of hypermedia as enabling rather than directive, offering more learner control over the learning process than is available through traditional methods of information presentation. This is especially relevant in the science classroom where the time necessary to comprehend difficult scientific concepts varies drastically from individual to individual. This difference can be accommodated in the hypermedia milieu, since learners have direct control over the pace at which they progress through the material.

Another theoretical concern has been that of *inert knowledge*, a term coined by Albert North Whitehead (1929) to describe knowledge that people possess but fail to use. A number of research studies at Vanderbilt University have dealt with this problem (e.g. Bransford, Franks, Vye, & Sherwood, 1989; Cognition and Technology Group at Vanderbilt, 1990; Sherwood, Kinzer, Hasselbring, & Bransford, 1987; and Bransford, Sherwood, Hasselbring, Kinzer, & Williams, 1990). Out of these studies has come the framework for a model of instruction called *anchored instruction*. According to Bransford, Sherwood, Hasselbring, Kinzer, & Williams (1990), "The major goal of anchored instruction is to enable students to notice critical features of problem situations and to experience the changes in their perception and understanding of the anchor as they view the situation from new points of view" (p. 135). One of the most effective anchors, according to these authors, is achieved through the use of video. It therefore becomes immediately apparent that hypermedia presentations incorporating video segments allow curriculum specialists to create materials which include these theoretical *anchors*.

Bransford, Franks, Vye, & Sherwood (1989) note that, "Even visually based presentations of problems will not necessarily develop the skills required to find and discover important features, issues, and questions" (p. 493). They point out that the salient features of a problem situation noticed by an expert in the field are quite often different from the features noted by the novice. One way of enhancing learning, then, is to help students see the features as an expert would see them, and to use contrasting segments of video to help students discover important features on their own.

Hypermedia presentations incorporating these theoretical considerations may become very important in the presentation of scientific concepts. A hypermedia presentation on chemical kinetics could be linked to a videodisc segment which would allow students to work with the reactants, control the reaction speed, and explore step by step the reaction pathway. By allowing the students to see contrasting segments of video and discover for themselves the important differences that result from varying the conditions of the reaction, students may be able to speed up the process by which they achieve the "internal contexts of alternatives for perceiving subsequent events" spoken of by Bransford, Franks, Vye & Sherwood (1989, p. 492). In addition, such a presentation would allow individual students to proceed at the pace that would be optimal for them.

There are certain abstract concepts in science which would be hard to present at the concrete level without the ability to invoke simulations. Although hypermedia technology was not directly designed for simulations, with the use of interactive videodiscs it can be used for steering simulations. An example of a hypermedia application controlling a simulation can be found in the teaching about mole ratios. It is difficult to conceptualize how one mole of oxygen and two moles of hydrogen can combine to form two moles of water. By linking hypermedia stacks to a videodisc presentation, the learner could see how three moles of a reactant could become two moles of a product. This ability to present abstract concepts in a more concrete mode is a definite attribute of these applications.

> *"Marchionini has characterized the learning environment of hypermedia as enabling rather than directive."*

Finally, the integration of learning across subject area boundaries is another prime concern of curriculum-designers. One of the objectives of science education should be to equip students to be more aware of the role of science and technology in every aspect of human life, and to enable them to address societal issues stemming from science (Lewis, 1981). In this context, hypermedia applications offer limitless opportunities to link science, technology, and society (Kumar, 1991). The browsing and navigational capabilities of the hypermedia environment can be fully exploited to design learning materials which present a multidimensional view of science. For example, acid rain is a scientific topic of societal importance. Using a hypermedia presentation, it would be possible to present to the students, not only text materials, but also newspaper clippings, court decisions, expert opinions, and pictures of trees spoiled by acid rain. Thus the learner would get a multidimensional view of acid rain. This would help the student understand the topic in the context of its impact on society.

Promotion of Scientific Inquiry

McAleese (1988) presented an argument for using the navigational aspects of Notecard for knowledge acquisition and exploration. *Notecard* is a software package for authoring hypermedia presentations. The environment, which simulates a stack of notecards, and the ease with which one can move through these stacks make it a powerful tool for inquiry learning. For example, teachers are provided with the tools necessary to design an inquiry lesson on chemical bonding. The inclusion of thought provoking questions could result in an incentive for student inquiry. As they navigate through the stacks and encounter these questions, students might be challenged to use more imaginative approaches to problem solving. This could only be accomplished with careful planning and design, however.

Russell, Moran, & Jordan (1988) have discussed an augmented version of *Notecard* used as a delivery vehicle for computer assisted instruction. It is possible that hypermedia authoring systems could be used in a similar manner as a guiding medium for laboratory experiments. Step by step procedures could be designed for chemical experiments, procedures which would guide students through the experiment. As Miller has noted (1988), it is much easier to understand a visual image of a procedure than to comprehend a verbal description. Therefore, it should be advantageous to link video simulations of the experiment setup, procedures to follow, safety tips, and graphic representations of the results. This should not, however, be construed as an invitation to remove the teacher from direct participation in chemistry laboratory activities.

Some On-going Research Projects

NSF Math and Science Project

Working under a grant provided by the National Science Foundation, Vanderbilt University is currently involved in a major restructuring of the mathematics and natural science components of their elementary teacher preparation program. This is a multifaceted program which includes the design of new science and math courses for education and liberal arts students and the integration of the laboratory experiences in these courses with the science and math methods courses. In addition, the project is using videodisc technology in a hypermedia environment to integrate filmed classroom examples into the laboratories for the basic science courses and into the math and science methods course.

In the past, beginning teachers have had a problem translating theory into practice. One reason is that they often lack a context for what they are learning in their foundations and methods courses and they therefore find it difficult to apply in an actual classroom situation the theory they have learned. In addition to knowing what the theories mean, prospective teachers need to believe that instructional strategies will work. And they need to have the management skills that will enable them to use instructional formats that allow students to engage in hands on activities and provide for student interaction in the problem solving process.

Because teacher education students often lack a context for understanding and integrating the theories they are learning in their foundations and method courses, part of this research is focused on the use of videodisc technology in conjunction with a hypermedia presentation that will allow preservice teachers to see the classroom culture in which certain instructional strategies are used. This is an application of the anchored instruction model discussed earlier. Through the use of a hypermedia presentation students are able to access information about instructional strategies, see a sample lesson plan that incorporates the strategy, and branch to video segments in which the strategy was employed. It is hoped that by incorporating focused classroom examples into the methods course lectures and activities, students will gain a context for understanding, integrating, and applying the information that is presented in the math and science education coursework.

Although we have thus far confined our discussion of the uses of hypermedia mostly to presentations that involve the computer as the primary presenter of information, there is a sense in which the term hypermedia may apply to other vehicles of instruction. One of the distinguishing characteristics of hypermedia presentations is the structuring of information in a way that allows users to determine the sequence in which they will access the information. There is often a hub of information around which other types of information may be linked. In addition, these presentations usually use some sort of technology. Following are descriptions of two different research projects at Vanderbilt University which provide information in a way that allows for instant access and individualization of the order of access. In addition, they both incorporate the concept of *macro-contexts* within the framework of an anchored instructional model. As Van Haneghan, Barron, Young, Williams, Vye, & Bransford (in press) have stated, "A primary requirement of anchored instruction is that the teacher and student share a rich context [a macro-context] to which many types of information can be linked" (p. 1). In the following example, information is linked to the macro-context itself, and the macro-context becomes the hub around which information and activities are organized.

The Jasper Series

Another anchored instruction project, this one funded by the James S. McDonnell Foundation and the National Science Foundation, has as its primary focus the formulation of mathematical problems and problem solving. It involves the development and evaluation of a series of adventures of a character named Jasper Woodbury. The adventures are professionally produced movies, lasting approximately 15 minutes, presented on videodisc. They are designed for use with fifth and sixth grade students although they have been used effectively with fourth graders all the way to college students. Currently four of a projected six episodes have been completed and field testing is underway in a number of public schools.

In discussing the problem of inert mathematical knowledge among children, or the failure of children to spontaneously use concepts and procedures they have mastered, Van Haneghan, Barron, Young, Williams, Vye, & Bransford (in press) state,

> *One reason that the knowledge acquired from such activity becomes inert is that it does not represent an analogue of real world problem solving. Applied problem solving involves more than simply figuring out which procedure to apply. It involves constructing the question itself and finding the information necessary to solve the problem (in press).*

The Jasper discs address this problem by providing an adventure story about Jasper Woodbury as the macro context within which a large number of activities will be situated. One of the design features of the adventures is that they contain *embedded data*. In other words, the data necessary to solve the question posed at the end of the adventure is contained within the context of the adventure itself, much as it is in real-life situations. Children must not only understand what the question is, but they must also decide what information is relevant, what sub-problems must be identified, what processes will yield a solution to the problem, and what sequence in which to proceed. Each adventure poses a different problem and each problem involves "the generation of approximately 15 subgoals....All the data needed to solve the problem are embedded in the story" (The Cognition and Technology Group, 1990, p. 5). "The embedded data design," reports the Cognition and

> *"One of the distinguishing characteristics of hypermedia presentations is the structuring of information . . ."*

Technology Group, " allows teachers to help students try to generate what they need to know, attempt to retrieve this information from memory, and then scan back on the disc to see if they were accurate" (p. 6). Once again we see the macro context as a hypermedia presentation in that it is a hub around which other information is linked, it can be accessed in any order necessary, and it makes use of advanced technologies to accomplish these functions. (See Van Haneghan, Barron, Young, Williams, Vye, & Bransford, in press, Cognition & Technology Group, 1990 and Bransford, Kinzer, Risko, Rowe, & Vye, 1989, for a more complete description of the Jasper Series and other Vanderbilt Projects.)

Problems and Possibilities for Further Research

Although hypermedia has been touted as a panacea for educational reform, there are some inherent problems with it that will have to be overcome before it is able to fulfill its potential. The problem mentioned most frequently in the literature is the fact that users tend to become disoriented, especially in large systems (Smith, 1988, p. 39; Jonassen, 1988, p. 14; Marchionini, 1988, p. 10). Several ways of dealing with this problem have been devised. Maps of the entire system showing every possible link are one possibility. *Intermedia*, a hypermedia system developed by Brown University in 1985, is one system that uses this approach. *Intermedia* contains two features: the global map shows all the links in the system, and the local tracking map shows all the links from the current document. At the time of the article (1988), Smith reported plans to redesign the maps so they would show the path the user had traversed to arrive at the current location (p. 40). She suggested that this was an area that needed further investigation.

Jonassen (1988) found a related problem in knowing where users should access hypertext. He hypothesized that the access point might have an affect on the user's understanding (p. 14) This access point, termed the root document by Kearsley (1988), "is the first document you see when you start up a hypertext database" (p. 22). Kearsley suggested several strategies to use in designing the root document: (a) The root document could be an overview showing all the major concepts in the database. He calls this the glossary approach. (b) It could use a hierarchical approach in which the links in the root document are major categories. This is the top-down approach. (c) It could use a menu approach in which all the articles on the root document are arranged as a list or table of contents of major concepts in the database. Or (d) It could use a tutorial approach in which the root document is used to give the user a tour of the data base. He suggests that the purpose of the database will determine which of the approaches is most suitable (p. 22). This might also be an area that would yield valuable information to the potential researcher. It would be important to know if any of these approaches leads to superior comprehension on the part of users.

Jonassen (1988) stated that an additional problem with hypermedia resides in the fact that,

> *. . . the less structured hypertext is, the less likely users are to integrate what they have learned. Without explicit external organization, many learners have difficulty acquiring new knowledge. 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). (p. 14).*

In his 1986 article Jonassen stated that of several levels of hypertext structure, hierarchical structure was most consistent with Ausebel's cognitive theory (p. 282). The levels of structure described by Jonassen are consistent with the types of root documents described by Kearsley. The hierarchical structure is much more rigid than, for instance, the chunked, or linked node that he described earlier in the article. In this type of structure the user is restricted in the moves he can make, so that he is only allowed to move up and down through the hierarchy to superordinate or subordinate concepts, but has limited access to lateral moves. Theoretically this would force the user to improve his own cognitive framework, but this also is an untested hypothesis that might lend itself to further research.

An alternative method of providing for the integration and assimilation of knowledge into a student's existing knowledge structure is suggested by Sherwood, Kinzer, Hasselbring and Bransford (1987). They suggest that the use of video-based technologies, through the inclusion of segments of films, might provide a macro context that would help students by providing a framework into which new information can be incorporated.

A further caveat comes from Christopher Dede in a paper presented in Dallas, Texas in June, 1988: "The richness of non-linear representation carries a risk of potential intellectual indigestion, loss of goal-directedness, and cognitive entropy" (cited in Jonassen, 1988, p. 14). In other words, for the inexperienced learner, it is possible that the sheer amount of information coupled with the decisions necessary as to what information to pursue, may produce a cognitive overload in the user and result in poorer integration of new information than would have been obtained with a traditional method. This also remains to be seen as there is little data on which to make an evaluation.

Summary

The use of hypermedia in conjunction with recent electronic technology offers great hope for the schools of tomorrow. It offers a way not only to present information, but more importantly, to enable students to better integrate new information with their existing bases of knowledge and to become competent handlers of information and better decision makers. Furthermore, the potential advantages of hypermedia applications in science instruction are many, ranging from more effective ways to present information, to affective and cognitive aspects of learning. However, it remains to be seen whether this new medium can overcome some of its inherent difficulties and if indeed the theoretical foundations on which it is based will actually work in a practical setting. It may be that hypermedia applications will be the tool Bush (1945) envisioned over forty years ago when he talked about a tool capable of disseminating enormous quantities of information that would be a direct and powerful extension of the human mind. ❖

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