The Effects of Cognitive Style and Knowledge Structure on Performance Using a Hypermedia Learning System

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ABSTRACT

Hypermedia software is quickly becoming popular with many educational institutions and curriculum programs. One of its major attractions is that it allows for the flexible structuring, construction, and exploration of the knowledge domain. The purpose of this research study was to determine the relationship among the cognitive style (active and reflective), the structuring of the knowledge domain as controlled by the hypermedia software (hierarchical, branching, and conventional), and the test performance of the learner (in terms of cognitive skill levels). More specifically, a controlled group experiment with 115 pre-adolescent, elementary school students (fifth-graders) was conducted. An immediate written posttest, used to assess the subjects' learning performance in terms of total, higher-order, and lower-order cognitive skills, was administered. Significant differences were found among the three knowledge structure schema groups for the total and the higher-order cognitive skills performance scores. No significant relationship was observed between cognitive style and performance, nor did this variable significantly interact with the knowledge structure variable. The major conclusion from this study is that a relationship exists between the structuring of the knowledge domain, as reflected by the hypermedia software, and positive learning performance. This relationship is also extended to the effective use of higher-order cognitive skills.

INTRODUCTION
Information technology has historically played a central role in the delivery of instruction in the classroom. Over the years, teachers have used books, television, projectors, and many types of lab equipment as tools to help them transfer knowledge to their students (Hawkins, 1993). In the past decade, computers have been added to the teacher's technology toolbox. Like no other previous technology, it has been able to capture the imagination of educators (Soloway, 1993). Today, computers can be frequently found in classrooms and laboratories throughout our schools, universities, and other educational and training institutions.

Experience and previous research on the effectiveness of computer technologies have consistently revealed that, when used appropriately, computers make excellent learning tools (Snider, 1992). In the classroom, the applications of computers have evolved from the provision of drill and practice for remediation, to later providing structured curriculum and instruction. Today, the computer is often used for knowledge exploration and construction. Often quoted benefits include, among others: Learner pacing of instruction, interactive quality, immediacy of feedback, and learning individualization (Hawkins, 1993).

Of these attributes, individualization and interactivity have commonly been viewed as central in making the computer the learning tool of choice in the classroom of the future. Specifically, it seems that by carefully choosing the appropriate software, the
computer has the inherent flexibility to accommodate a variety of student learning styles (Hawkins, 1993; Schank, 1993). Furthermore, its interactive nature seems to be ideal for exploring knowledge (Hawkins, 1993; Oren, 1990). Computing technologies have had such a significant impact in education that many people believe the computer has the potential to transform today's teacher-centered classroom into tomorrow's learner-centered classroom. This transformative role of technology is seen to be at the top of the agenda of many educational reform initiatives (Hunter, 1993; Pearlman, 1993; Sheingold, 1991; Snider, 1992).

On the technological front, during the past decade, the computer has evolved from being a command-line instructional machine. Graphical and friendlier user interfaces have made human-computer interaction much easier and more effective. Today, computers inexpensively and easily provide highly interactive multimedia information (text, sound, images, and video) to its users. Furthermore, these interactive multimedia systems may now be programmed to deliver hypermedia (Dede, 1992).

Hypermedia software stores information in networks of nodes connected by links (Ambrose, 1991). The nodes can contain text, graphics, audio, data, video, or any other form of media. To the user, hypermedia programs are nothing more than knowledge databases guided by menus and/or icons (Locatis et al, 1992). The essence of hypermedia is the instantaneous and dynamic linking of concepts within the various knowledge
domains, resulting in a series of nonlinear connections. To facilitate navigation, an
interface or "browser" is provided for moving around the knowledge base.

Hypermedia is the result of the evolution of its predecessor, hypertext (nodes
contain only textual information). Over the years, this technology has evolved to
incorporate many types of media. Today, hypermedia is commonly available with many
different types of computer systems (PC, Mac, and others) and formats (floppy disk, CD-
ROM, CD-I, etc.). However, the most recent hypermedia development effort could
potentially be the most revolutionary. The integration of hypermedia technologies with
high-speed computer networks has made the development of the Internet's World Wide
Web possible (Soloway, 1995). The wide-reach of the traditional Internet network (global
in scope), coupled with the multimedia capabilities of the computers it interconnects,
have made the World Wide Web a truly international and highly distributed hypermedia
system. This new and exciting form of hypermediated network is widely used in
education, and is becoming a popular tool for creating a self-directed and exploratory
learning environment within many classrooms (Dern, 1993, Soloway, 1995).
REVIEW OF THE LITERATURE

Over the past decade, a number of studies have explored the effects of hypermedia on learning. A review of the literature by Ambrose (1991) has revealed a few interesting research questions. The more pertinent and interesting ones for this research study are: What type of learner is most likely to effectively utilize a hypermedia environment? Do students using hypermedia materials learn more effectively than those using more structured traditional material (i.e. using a more linear medium)? Does the use of hypermedia materials encourage learners to employ higher-level thinking skills?

Furthermore, a research review study of hypertext by Tsai (1989) also raised some similarly interesting questions. The more salient and pertinent of these is: Will learners form better conceptual models using hypermedia or will the richness of the information overload learners and impair effectiveness and efficiency of learning?

In assessing the effects of hypermedia on learner performance, the above questions can be classified as addressing the understanding of two major issues, learner characteristics and learner control. This research study will examine the empirical studies associated with these issues. The research will address the effects of the learner's characteristics (by specifically examining cognitive style) and the learner's level of
self-direction (by addressing the structuring impact of the knowledge domain) on the
performance of students when operating in a hypermedia learning environment. The
performance will be examined by evaluating the use of higher-level cognitive skills
as well as the overall achievement test scores. The research which address the above two
factors (cognitive style and knowledge structure) will be more fully described in the
following sections.

**Cognitive Style**

Although used interchangeably in the literature, there is a technical difference
between the use of the terms cognitive style and learning style. Cognitive style deal with
the "form" of cognitive activity (i.e., thinking, perceiving, problem solving, etc.), not its
content. It is viewed to be "persuasive dimensions" of personality, bipolar in nature, and
stable over time (Whyte, Karolick, Nielsen, Elder, & Hawley, 1995). Learning style, on
the other hand, is seen as a broader construct, which includes cognitive along with
affective and physiological styles (Keefe, 1988). Therefore, the distinction being made, it
should be clearly stated that this research study will deal with cognitive style, even
though at times the term learning style will be used (mostly in reference to previous
research).
When it comes to the use of hypermedia, what type of learner is most likely to effectively utilize a hypermedia environment? A theoretical study review by Locatis et al (1992) claims that:

Persons already sophisticated in the subject matter or who have high general ability may learn most from hypermedia. Since sophisticates are likely to have representations similar to those authoring the knowledge, they may navigate links and process information more appropriately....Lower ability students might benefit if there is extra guidance. (p. 73)

Thus, Locatis et al (1992) seem to imply that learners having general ability (e.g., cognitive style) should perform well in a hypermediated environment. Overall, hypermedia offers the potential for new strategies of learning, teaching, studying, and creating. An experiment with 63 undergraduate students using hypermedia studied the major effects of learning style preferences, GPA, and attitudes on learner achievement. It showed that GPA had a significant and positive correlation with achievement. However, this conclusion was observed only when GPA was included with the attitude scale into the regression analysis (Billings & Cobb, 1992). According to the authors, their results seem to contradict previous studies which found found no relationship at all between attitude and achievement and an insignificant interaction between learning style, attitudes, and achievement (Billings & Cobb, 1992).
Another field study of adult computer technicians located throughout the country examined the relationship between learning style and the effectiveness of an interactive video instructional system (Larsen, 1992). The results failed to detect any significant correlation between learning style and achievement scores.

An experimental study by Yung-Bin (1992) tested the effects of learning style and on-line instructional advisement on undergraduate students' achievement test performance. The results indicate that achievement test scores were affected by the interaction of learning style and advisement, with active-learning subjects tending to score higher on the achievement test than passive-learning subjects. Furthermore, passive-learning subjects who received the advisory version of the software scored significantly higher on their achievement test than passive-learning subjects who had the non-advisory version.

Finally an experiment by Jonassen and Wang (1993) involving ninety-eight pre-service teachers in an open enrollment college showed that individual differences interacted with learning through the use of hypermedia. The research showed that the "field independent processors" cognitive style subjects generally preferred to impose their own structure on information rather than accommodate the structure that is implicit in the materials. The authors conclude by stating that it is likely that field independent learners are better hypermedia processors, especially as the form of the hypermedia becomes more referential and less overtly structured (Jonassen & Wang, 1993).
In summary, the research, albeit mixed, indicates that learners with certain cognitive styles (labeled active, exploratory, or field independent) should perform better in a hypermedia learning environment than those with others. However, this assertion seems to be more the case when cognitive style interacts with other factors, such as attitude and advisement (Paolucci & Wright, 1996).

Knowledge Structure

Will learners form better conceptual models using hypermedia or will the richness of the information overload learners and deteriorate effectiveness and efficiency of learning? According to Marchionini (1988), "Although self-directed and exploratory learning are worthy objectives to achieve in learning environments, freedom to learn does not seem to be a sufficient condition to assure effective learning." (p. 11). The point to be made here is that freedom can be confusing, since it increases decision-making load. Attention may be diverted from content and relationships as learners attend to navigational decision-making and disorientation may be experienced. This problem may be compounded by the vast quantities of easily accessible information, much of which may only be peripherally relevant.
Thus, it seems, the rich learning environment can easily become a trip into "hyperspace" (Marchionini, 1988). However, Tsai (1989) claims that this issue can be adequately addressed, "Even though users can freely choose their browsing paths, a hyperdocument has an intrinsic structure which is determined by how the nodes are linked together. This intrinsic structure should have some effects on users' browsing and commenting activities." (p. 11). This is similarly noted by Conklin (1987), with his claim that there is no natural topology for an information space.

These observations raise yet another interesting question: Are some knowledge structure schemas better than others in facilitating and promoting learning in general, and higher-cognitive skills in particular? Are there schemas that are better suited for certain cognitive styles? Empirical studies on this subject have yielded different results. The first investigation by Stanton (1994) examined the comparison of a learning environment that presented the instruction knowledge in a linear format over which the student had no influence, with another in which the student was able to determine the sequence of the instruction freely. The study results, involving forty adult students, suggest that performance may be improved in the non-linear learning environment, but this is likely to be dependent upon the ability of the participants to organize the environment in a manner that suits their own learning style. Stanton's findings also support the theoretical research of Brooks, Simutis, and O'Neil (1985), who claim that learners may actually be able to
process information more effectively if it is presented in a manner that is closely matched by their learning style.

However, a study by Jonassen and Wang (1993) involving ninety-eight pre-service teachers in an open enrollment college indicated that merely showing learners structural relationships is probably not sufficient to result in greater structural knowledge acquisition or performance. The authors observe that:

It appears that arbitrarily imposed semantic nets are not adequate to overcome the personal ones or at least not directly mapped onto the learners. What seems to matter most is the construction of personally relevant knowledgestructures. (p. 7)

The authors claim that such constructions can promote higher-order thinking in the form of logical reasoning. Furthermore, a study of health care employees by Cordell (1991), designed to determine whether knowledge structure and learning styles affect outcome, revealed insignificant and unclear results. Similarly, a study by Rasmussen and Davidson (1996) with pre-service teachers as subjects did not yield a significant relationship between hypermedia structure and performance; however, the results showed a significant interaction between learning styles (active-reflective) and hypermedia structure (hierarchical). Thus, although only a few empirical research studies exist on this topic, there seems to be no clear empirical evidence substantiating the theoretical claim that the structuring of the knowledge domain onto the hypermedia courseware, and its use, has any relationship to learning performance.

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Having examined the dimensions of cognitive style and knowledge structure, the questions of effectiveness in terms of performance skills remain. Does the use of hypermedia materials encourage learners to employ higher-level thinking skills? Is there a relationship between the hypermedia knowledge base structure and the promotion of higher-order cognitive skills?

It has been a commonly held view that discovery learning environments are ideal for stimulating higher-order thinking (Schank, 1993). These views have been discussed and documented at length by such noted cognitive theorists as Bloom (1956) and Gagne (1977). In using hypermedia environments to teach high-level learning skills, Locatis et al (1992) claim that:

Hypermedia might best be used when discovery learning is warranted. Since discovery implies teaching the process of learning as well as acquisition of content, students might be encouraged to construct their own knowledge representations and to refine and reflect upon them periodically in the course of exploring a hypermedia knowledge base to solve problems -- a strategy analogous to one used by some intelligent tutoring systems to ensure knowledge is properly understood, integrated and remembered. (p. 73)

Much theoretical research in this area seems to imply that hypermedia improves learning by focusing attention on the relationships of ideas, rather than isolated facts, facilitating
concept formation, understanding, and association (Ambrose, 1991). According to some, in tracking the subject's navigational patterns when using a hyperdocument, the learner constructs a knowledge map by specifying the relationships between concepts in the domain (Nelson, 1992). The resulting map can be used to recognize the learner's conceptual associations, in addition to recognize the learner's misconceptions (Kumar, 1994).

However, the empirical research on the assessment of higher-order thinking skills using hypermedia software seems to indicate, but does not directly establish, such a relationship (Jonassen and Wang, 1993). Moreover, the number of studies that buttress this theoretical claims are almost non-existant.

**METHODS**

As hypermedia technologies become more commonly used in education, students, teachers, instructional designers, and administrators need to understand how these can be applied to enhance the instructional and learning processes. Toward this end, it is important for those teachers who wish to be local producers of hypermedia courseware (through the use of authoring software) to understand the implications of structuring knowledge in their design of the hyperlessons (Cates, 1992; Tolhurst, 1992).
It is equally important to identify those learner characteristics or factors (e.g., cognitive styles) that foster effective use of the hypermedia systems, so that teachers can match and accommodate these to the proper learning environment. Finally, it is imperative for teachers and administrators to understand how the structuring of hypermedia, if done well, can foster and augment a variety of student learning skills.

The purpose of this research study is to evaluate the effects of cognitive style and the structuring of the knowledge domain, as represented by the hypermedia courseware, on the learning performance of young adolescent elementary school students.

**Research Design**

An experiment was performed with six classrooms of early adolescent elementary school students (fifth-graders). The experiment took place near the end of the school year. Hyperdocuments developed specifically for this study, using hypermedia authoring software, was used as learning systems in delivering a short unit of instruction.

The subject matter used in the development of the hyperdocument lesson was in the science domain, more specifically a lesson unit on "ecology". The choice was influenced by both its relevance to the curriculum, and the high interest level that
has historically been shown by the students on this topic. However, and more importantly, it should be noted that this topic was mainly chosen to control for the subjects' prior knowledge, since this factor can have an impact on the effectiveness of the hyperlesson. The objective was to choose a topic with which the subjects were somewhat familiar, in order to provide a decent knowledge base to facilitate further learning. Moreover, the knowledge base had to be somewhat equivalent for all participating subjects, in order not to bias the performance outcomes of the experiment.

A lesson on Ecology met both requirements, all fifth-grade students in the population had received a "hands-on" activity lesson on ecosystems in the beginning of the school year, months prior to the research experiment. Given this, it is safe to assume that the subjects' level of prior knowledge on the topic of ecology was relatively the same, and hence not considered to be a factor on the outcome of the research study. Furthermore, since all participating students had a familiarity with the basic concepts of an ecosystem, the hypermedia lesson on ecology could build on this knowledge base and facilitate additional learning.

The hypermedia software was programmed and structured to produce three different hyperdocument options, each designed to reflect three different and widely used schemas in the structuring of the knowledge domain. These are, conventional (the nodes and links of the hyperdocument allow for significant navigational freedom and self-
direction), branching (the nodes and links of the hyperdocument allow for a moderate degree of navigational freedom and self-direction), and hierarchy (the nodes and links of the hyperdocument allow for little navigational freedom and self-direction). It should be noted here that, although structured differently, all three hyperdocuments contained the exact same information or knowledge base.

The six classrooms, and their respective student subjects, were randomly subdivided into three different groups (each allowing the use of the three hyperdocument versions). All six participating teachers were instructed to review the previously given activity lesson on ecosystems, and relate this information to the use of the ecology software. Students were also informed that they would have to take a written test upon completion of the hyperlessons. To provide an incentive to perform well, the teachers informed the students that the results of the test would be used for extra credit. After receiving some preliminary instructions by the teachers and the researcher, the students used the hyperdocument in a computer classroom for 40-45 minutes. All classrooms were equipped with multimedia-ready Macintosh computers that easily allowed for the use of the hyperdocuments.

The exposure and use of the hyperlesson was repeated approximately a week later; once again, in the schools' computer classroom. A written performance posttest, designed to evaluate the levels of student performance in terms of higher and lower level cognitive
skills, was administered by the participating classroom teachers and given to all students immediately after the second exposure.

During this period, a written test was also administered to determine the students' cognitive styles. It is worthwhile to note here that, in order to minimize the influence of the research study on the normal classroom organization and procedures (and perhaps outcomes), both tests were administered by the classroom teachers.

Finally, in order to get a baseline measurement of the effectiveness of the hypermedia learning system, an additional fifth-grade classroom was chosen to participate in the research study as a control group. Naturally, the student subjects in this control group did not get to use the hyperlesson on ecology, but were asked to take the written performance test.

Population and Sample

The sample for this study consisted of six, fifth-grade classrooms of students in a suburban, middle-income school district. The classrooms and students were located in three different elementary schools. All of the students and their respective teachers were computer literate, deliberately chosen to control for this factor in the study. The original total number of participating student subjects was 131.
The six classrooms of children were randomly assigned one of three specific versions of the hyperdocument. In all, they formed three distinct groups, each reflecting three schemas or levels of knowledge structure representations. This method was chosen over other options, including the one where students in each classroom are randomly subdivided into three groups, with each group using one of the three versions of hyperdocuments. It was felt that having students using different versions within the same classroom would promote discussion and comparison, potentially biasing, contaminating, and invalidating the results (Borg & Gall, 1989).

Thus, each of the three hyperdocument versions was used by two teachers, each expected to have an approximately equal number of student subjects. It was also expected that each of the three hyperdocument versions would have an approximate equal number of subjects representing the different cognitive styles.

Instrumentation

In performing the research experiment described above, four different instruments were used to develop the necessary factors that formed the set of independent, covariate, and dependent variables. These instruments are: The hyperdocuments, the cognitive style
assessment test, the Comprehensive Test of Basic Skills (CTBS), and the learning performance test.

**Hyperdocuments.** The hyperdocuments used in this research study were developed using HyperStudio(TM) multimedia authoring software for the Macintosh computer platform (Wagner, 1995). Much research has been performed on techniques for authoring and structuring hypermedia software (Kearsley, 1988). However, as shown in Figure 1, three major design approaches or schemas have emerged from this work: Conventional, Branching, and Hierarchy (Locatis et al, 1992; Misanchuk & Schwier, 1991).

With the conventional approach (see Figure 1a), most topics are linked referentially on the assumption that students can begin learning some subjects when requisite knowledge is only partially grasped. Students can freely access any of its nodes. The nodes and links of the conventional hypermedia document are relatively unstructured, allowing for a high degree of self-direction.

With the branching approach (see Figure 1b), the learner is presented with choice points or nodes at which different responses will result in different alternative paths through the instruction. In some cases, access to lower level nodes might be blocked until all nodes at higher levels are viewed. The nodes and links of the branching hyperdocument are somewhat structured, allowing for a medium degree of self-direction.
Finally, with the hierarchy approach (see Figure 1c), links are only established between nodes containing information prerequisite to others. Users do not access nodes teaching higher level skills until those at lower levels are accessed. The nodes and links of the hierarchical hyperdocument are more tightly structured, allowing for a lower degree of self-direction (Locatis et al, 1992; Misanchuk & Schweir, 1991).

At one extreme, the conventional hyperdocument will allow the student-user a greater degree of freedom in exploring the knowledge domain. At the other extreme, the hierarchical hyperdocument will allow the student-user less freedom in exploring the subject's domain.

Thus, the hypermedia authoring software used in this research was programmed to produce three distinct hyperdocuments (coined HyperEcology for the purpose of this research study). These were developed to reflect the three distinct schemas or approaches to knowledge structuring and representation described above. It is important to note that, although the hyperdocuments were structured differently, their informational content or knowledge database were identical.

Although it is very difficult to capture the essence of the three versions of the ecology hyperdocuments without the use of a computer, it is valuable to illustrate their schemas on paper. Figures 2 and 3 represent two of the three HyperEcology software
knowledge structures schemas, hierarchical and branching, respectively. Note, that the conventional schema is not shown. The reason is due to the fact that the number of links associated with this schema is fairly high. Thus, its figure would be confusing to visualize and difficult to depict. To illustrate this point, the hierarchical hyperdocument is comprised of 39 nodes and 37 links, the branching of 39 nodes and 50 links, while the conventional of 39 nodes and 173 links.

[Insert Figures 2-3 here]

It also worthwhile to note that, for the hierarchical hyperdocument, each of the screens was designed to allow the users to go back to the previous branching point (if one existed). When the very bottom of the branch is reached, the user has the ability to go back to the very top of the branch. The navigational design methodology for the branching hyperdocument was exactly the same as the hierarchical, with the exception that the user is allowed to branch out. However, in this case, the user cannot immediately go back to the branching out point, but is instead provided with the choices of the new branch. The links for the conventional hyperdocument were determined by the frequency of the keyword titles associated with each node (e.g., the term "water" was linked to the node "water" each time it appeared in any of the other nodes or screens). In essence, once the program was started, the users of this schema did not have a way to go back to the beginning of the program. Since with the conventional schema, there is no beginning and
end or top and bottom (although all the screens are connected and have many links among them).

Therefore, it is important to note that while the hierarchical hyperdocument allows the user to easily visit all the screens (nodes) with some opportunity for exploration but no disorientation; the branching hyperdocument allows for more exploration and possible disorientation (although, the user has the ability to overcome these events and visit all the screens); the conventional hyperdocument allows for a significant degree of freedom for self-exploration but also for significant disorientation. It is important to note that, with the conventional hyperdocument, the fact that not all screens will be necessarily searched and viewed by its user is a distinct possibility.

Cognitive Style Assessment. The instrument used in this research study to assess the subject's cognitive style was the Kolb's Learning Style Inventory (Kolb, 1984). This instrument has consistently been shown to possess both adequate reliability and validity (Kolb, 1976; Smith & Kolb, 1986).

Kolb defines four learning styles, corresponding to each possible dimension combination: Diverger (ability for viewing concrete situations from many different points of view), Assimilator (ability to understand a wide range of information and putting it into concise, logical form), Converger (ability for finding practical uses for ideas and theories), and Accommodator (ability to execute plans and take risks). The theory claims
that students with different learning styles respond differently to the various instructional strategies, and that these should be matched in achieving effective learning (Smith & Kolb, 1986).

Kolb's learning style theory also claims that these four styles can differ and be viewed along two different cognitive continuums or dimensions: Concrete Experience-Abstract Conceptualization and Active Experimentation-Reflective Observation (Kolb, 1984). The first dimension is an assessment of the way people perceive information, with some people preferring to sense and feel their way (Concrete Experience) while others preferring to think their way through (Abstract Conceptualization). Along the second dimension, how information is processed is assessed, with some people preferring to jump in and try things (Active Experimentation) while others preferring to process new information by reflecting on it (Reflective Observation).

According to the theory, the extremes of each dimension are mutually exclusive. For example, it is claimed that individuals cannot simultaneously perceive by Active Experimentation and by Reflective Observation, since these will produce a conflict situation when presented with new information. The individual, in resolving this, must choose how to perceive and process new information. Thus, each person develops a preference by making frequent and successive choices in patterned ways.

The result of the above is a cognitive style, which is defined as the characteristic way an individual generally chooses to perceive and process new information (Kolb,
The Concrete Experience mode is included in the Diverger and Accommodator learning styles, the Abstract Conceptualization in the Converger and Assimilator learning styles, the Active Experimentation in the Converger and Accommodator learning styles, and the Reflective Observation in the Diverger and Assimilator learning styles. It is important to note that this research study is designed to focus on the information processing (Active Experimentation and Reflective Observation), rather than the perceptive dimensions of the Kolb's four learning styles.

**Reading.** Since the reading level is an important contributing factor towards the learning performance outcomes of the student subjects, an instrument to assess this level was required for this research study. The Comprehensive Tests of Basic Skills (CTBS) was employed to accomplish this (CTB/MacMillan, 1989). Reading is one of three sub-tests (along with language and mathematics) that form this standardized achievement test. Furthermore, the total reading sub-score has two components (vocabulary and comprehension). The data used in this research study was the national total reading percentiles scores of the participating student subjects. A percentile score indicates that the student is performing at that level higher than other students who have taken the CTBS nationally standardized test.

**Performance Assessment.** In order to evaluate the student subjects' performance after
using the hypermedia document, a written posttest was developed. This test was identical for all student subjects, regardless of which hyperdocument version was used in the experiment. The test is comprised of two cognitive sub-scores: Higher level skills and lower level skills. The higher level cognitive sub-score questions consist of four parts and is designed to assess the effects of the hyperdocument on the learners' structural knowledge, while the lower level cognitive sub-score questions is designed to assess the learners' informational recall skills.

One way of assessing higher-order thinking skills, as defined by Bloom (1956), is by assessing structural knowledge (Dierkhoff, 1983; Jonassen, Beissner, & Yacci, 1993). According to these researchers, structural knowledge is the knowledge of how concepts within a domain are interrelated. It mediates the translation of declarative knowledge into procedural knowledge. Questions used in testing this type of knowledge are of four types: Analogies, associations, relationship proximity judgments, and semantic relationships.

The analogies questions require students to assess similarities of concepts derived from the knowledge domain. The association questions require students to choose the strongest connection between two terms. The relationship proximity judgments questions require that students choose one or more correct alternatives associated with a particular idea, concept, or scenario. Lastly, the semantic relationships question requires students to...
identify the nature of the relationship among terms or concepts by connecting these into meaningful sentences. This part of the posttest consists of sixteen questions, for a maximum total of twenty points (these equally distributed among the four types).

In addition to the questions used to assess higher-order structural knowledge, fifteen multiple-choice information and recall related questions were developed to assess lower-order cognitive skills. Each of these is worth one point, giving a fifteen for a maximum score for this sub-score.

Thus, the total number of questions included in the posttest assessment instrument is thirty-one for a maximum total score of thirty-five points, twenty of these from higher-order cognitive skills questions and fifteen from lower-order cognitive skills questions. It is important to note that, what is of paramount significance to this research study is the "relative" performance scores of the student subjects, rather than their "absolute" performance scores.

Reliability and Validity

Hyperdocuments. All three hyperdocuments used in this research study were prototyped, previewed, and evaluated in concert with a participating expert teacher to ensure relevance to the curriculum and the appropriateness of the reading level of all textual
information. Furthermore, the prototypes were also evaluated by an academic expert in science education. Modifications were made throughout the design process to reflect both the experts' feedback on the subject domain and also to ensure the seamless integration of the courseware into the curriculum's lesson plans.

**Cognitive Style Instrument.** Historically, several types of learning or cognitive style instruments have been used to study the relationship between it and the effectiveness of hypertext and hypermedia (Dunn, Dunn, & Price, 1984; McCarthy, 1981). However, the Kolb Learning Style Inventory, was employed by this research study because it has consistently been shown to possess both adequate reliability and validity (Kolb, 1976; Smith & Kolb, 1986). Validity has been shown through significantly high correlations with similar instruments, including the Myers-Briggs Indicator (Kolb, 1976).

**Reading Level Instrument.** The Comprehensive Test of Basic Skills (CTBS) instrument is a historically established and respected standardized achievement test. It is widely accepted by the basic educational community as being one of the most valid and reliable indicators of curriculum and student progress (Sax, 1989).

**Performance Assessment Test.** In order to provide standards for performance assessment, a participating expert teacher reviewed the written performance test. Moreover, an
academic research expert in science education, along with the researcher and the expert teacher, agreed on the answers to each of the test questions. The test was also reviewed by a reading specialist in the district for appropriateness and clarity of language. Finally, the written test was piloted with a fifth-grade class to assess the level of difficulty in interpreting and understanding the questions. Many changes and modifications were made throughout this process in order to develop a written test that was appropriate, reliable, and valid.

Concerning the nature and form of the test questions, several procedures exist for assessing cognitive skills (Royer, Cisero, & Carlo, 1993). However, the previously described techniques used to assess the use of structural knowledge and higher order cognitive skills (Jonassen, Beissner, & Yacci, 1993; Dierkhoff, 1983), have been successfully utilized with hypertext software experiments (Jonassen & Wang, 1993). The method seems also to be best suited for this research study.

Data Collection

Almost all the research data associated with the previously described experimental variables (cognitive style, knowledge structure, and written performance test) were obtained during a three week period. However, the CTBS reading percentile scores data were readily available from the student records, since a version of this test (Grade 4.5
Level) was administered during the previous school year (Spring, 1995). The CTBS test is administered yearly by the district to all enrolled fourth-graders to determine whether a student needs remedial help in a particular subject.

RESULTS

All data were collected, with cooperation of the schools and participating teachers. Observations were performed in the computer classrooms throughout the experiment. Some students were also randomly chosen for brief interviews. The development of the three ecology hyperdocuments used in the study was a much longer process that spanned many months. This process also included cooperation and input from participating teachers and domain experts.

Data was also gathered on the student subjects’ reading levels by using their CTBS scores (CTB/MacMillan, 1989). The CTBS test is administered yearly by the district to all enrolled fourth grade students. A version of this test (Grade 4.5 Level) was administered to all fourth-graders during the previous school year. Therefore, the CTBS reading scores (in terms of percentiles) were readily available from the school records for those students.
enrolled in the district the previous year. Student subjects classified as "special education" or "learning disabled" were removed from all research analyses.

**Research Hypotheses**

The following are the four hypotheses identified and addressed by this research study:

1. There will be a significant relationship between the learner's cognitive style (active or reflective) and his/her performance, when using a hypermedia learning system.

2. There will be a significant relationship between the learner's usage of the knowledge structure schema reflected by the hypermedia learning system (hierarchical, branching, or conventional), and his/her performance.

3. There will be a significant relationship between the learner's usage of the knowledge structure schema reflected by the hypermedia learning system (hierarchical, branching, or conventional), and his/her performance in terms of higher-order cognitive skills.

4. There will be a significant interaction between the learner's cognitive style and the usage of the knowledge structure schema reflected by the hypermedia learning system, in relation to his/her performance.
Analysis of Covariance

The research data described above were examined by using the analysis of covariance (ANCOVA) statistical technique. In all cases, homogeneities of variance and regression were shown. An ANCOVA was performed for all three performance scores: Total, Higher Cognitive Skills, and Lower Cognitive Skills, with Reading as the covariate and a sample population of 115.

Table 1 presents the ANCOVA results for the Total Performance dependent variable, with Knowledge Structure (three groups) and Cognitive Style (two groups) as factors. A significance level of p=.05 was selected. As can be observed, the results showed a significant difference among the Knowledge Structure groups (F = 3.31, p < .05), but no significant difference between the Cognitive Style groups (F = .70, p < .05) was exhibited. Furthermore, no interaction between Knowledge Structure and Cognitive Style was observed (F = .17, p < .05).

[Insert Table 1 here]

In further exploring the statistically significant results associated with the Knowledge Structure groups, a post-hoc test was performed using the Student-Newman-Keuls procedure (Huck, Cormier, & Bounds, 1974). Once again, a significance level of p=.05 was selected. A significant difference between the Branching and Hierarchical...
groups (F = 5.58, p < .05), and between the Branching and Conventional groups (F = 6.68, p < .05) was found. No significant difference was found between the Hierarchical and Conventional groups.

Similarly, Table 2 shows the ANCOVA results for the Higher Cognitive Skills Performance dependent variable, with Knowledge Structure and Cognitive Style as factors. A significant difference among the Knowledge Structure groups (F = 4.05, p < .05) was found, but no significant difference between the Cognitive Style groups (F = .27, p < .05) was exhibited. Furthermore, no interaction between Knowledge Structure and Cognitive Style was observed.

[Insert Table 2 here]

A Student-Newman-Keuls procedure was used to further analyze the Knowledge Structure groups at a significance level of p=.05. This test showed a significant difference between the Branching and Conventional groups (F = 8.59, p < .05). However, no significant difference was found between the Hierarchical and Conventional groups and the Hierarchical and Branching groups.

Finally, Table 3 shows the ANCOVA results for the Lower Cognitive Skills Performance dependent variable, with Knowledge Structure and Cognitive Style as factors. The results showed no significant difference among the Knowledge Structure groups and between the Cognitive Style groups. Furthermore, no interaction between Knowledge Structure and Cognitive Style was observed.

[Insert Table 3 here]
FINDINGS

The objective of this research study has been to analyze the effects that the structuring of the knowledge domain (as reflected by the use of three major schemas), and the cognitive style of the learner had on performance when using a hypermedia learning system. Six fifth-grade classrooms from three different elementary schools within the same school district were chosen for the study. Each of the three hyperdocuments, specifically designed for this experiment, was randomly assigned to two classrooms. The domain of ecology was carefully chosen and used in this study to control for the students' prior knowledge.

All subjects used their assigned hyperdocument system on two different occasions, over a period of a week, in a computer classroom. A total of 115 students were represented in the experimental sample; 44 students in the hierarchical group, 38 students in the branching group, and 33 students in the conventional group.

Along with a cognitive style instrument, the students were also administered an immediate written posttest that assessed their learning performance in terms of higher and
lower-order cognitive skills. The performance results were analyzed to determine the
effects that the cognitive style and knowledge structure factors had upon the learner.

An analysis of covariance was used to control for the initial differences of reading
ability that might have existed among the three groups. The differences among the group
means were used to test the related hypotheses.

The following is a summary of the findings of the research study, regarding the
effects that the structuring of the knowledge domain and the cognitive style of the learner
have on performance when using a hypermedia learning system.

**Hypothesis 1.** The first hypothesis tested was that there would be a significant
relationship between the learner's cognitive style (active or reflective) and his/her
performance, when using a hypermedia learning system. No significant difference was
observed with any of the three performance mean scores for the two types of styles
considered in the study (active and reflective). Although the active styles group scored
slightly higher (M = 24.11) than the reflective styles group (M = 23.75) in both total
performance and higher cognitive skills performance, these differences were not
significant. On the other hand, the reflective styles group scored slightly higher
(M = 11.71) than the active styles group (M = 11.60) with the lower cognitive skills
performance. Once again, these differences were not significant.
**Hypothesis 2.** The second tested hypothesis was that there would be a significant relationship between the learner's usage of the knowledge structure schema reflected by the hypermedia learning system (hierarchical, branching, or conventional), and his/her performance. Significant differences were found with the total performance scores among the three knowledge structure schema groups ($F = 3.31$). Subsequent post-hoc tests revealed that the branching group performed significantly better ($M = 25.55$) than the hierarchical group ($M = 23.36$) and the conventional group ($M = 22.88$), with $F = 5.58$ and $F = 6.86$, respectively.

**Hypothesis 3.** The third test hypothesis was that there would be a significant relationship between the learner's usage of the knowledge structure schema reflected by the hypermedia learning system (hierarchical, branching, or conventional), and his/her performance in terms of higher order cognitive skills. A significant difference was found with the higher cognitive skills mean performance scores among the three knowledge structure schema groups ($F = 4.05$). A subsequent post-hoc test revealed that the branching group performed significantly better ($M = 13.32$) than the conventional group ($M = 11.21$) but not significantly better than the hierarchical group ($M = 12.23$), with $F = 8.59$ and $F = 2.82$, respectively. Furthermore, no significant relationship was detected among the lower cognitive skills mean performance scores of the knowledge structure groups.
Hypothesis 4. The fourth and final hypothesis tested was that there would be a significant interaction between the learner's cognitive style and the usage of the knowledge structure schema reflected by the hypermedia learning system, in relation to his/her performance. No significant interaction was observed between the two independent variables (cognitive style and knowledge structure) with any of the three learner performance scores.

DISCUSSION

The use of hypermedia software as learning systems does not necessarily lead to improved performance. As previously discussed, a high level of learner control, coupled with the rich learning environment provided by the hypermedia system, can lead to distraction and "hyperchaos". Under these circumstances, it is highly probable that learning will not occur, since students can either miss relevant instructional points, and perhaps form wrong interpretations of the information. Strategies for adding structure to hyperdocuments, such as those employed by this experiment, have been recommended to minimize this problem. The research findings seem to indicate that, the exploratory or navigational freedom associated with the knowledge structure schemas chosen for this
experient (hierarchical, branching, and conventional) did not distract the student subjects from the learning task at hand.

Thus, the research findings of this study show that properly structured hypermedia software can be effectively used as learning systems to improve performance and achievement. Moreover, it appears that the hypermedia systems provided an effective means for promoting and developing the learner's higher cognitive skills (e.g., analysis and synthesis).

The knowledge structure schemas used in the study (hierarchical, branching, and conventional), were chosen to provide a range of degrees of navigational or exploratory freedom. It seems evident from the findings that when "too much" freedom (as in the case of the conventional schema) or "not enough" freedom (as in the case of the hierarchical schema) is provided to early adolescent students in the form of a computer learning system, performance may suffer. This fact was evidenced by both the quantitative data analyzed above, and the numerous personal observations and student interviews conducted during the course of the study.

Although initially very enthusiastic, it was interesting to note that many student subjects became either easily bored (as was the case with the hierarchical group) or turned the learning system into a game (as was the case with the conventional group). Since the hierarchical knowledge schema allowed the subjects to easily visit all of the system screens in a relatively short period of time, many students in this group became
quickly bored after they had viewed and heard all the "cool" images, videos, and sounds. Even after repeated instructions from the teachers to read all the textual information, many appeared bored and restless.

However, with the conventional knowledge schema group, many students became intrigued with locating and replaying their favorite screen(s) (image, sound, or video). Since the conventional hyperdocument did not allow for this task to be easily accomplished, this became a challenging game for many students. Once again, even after repeated instructions from the teachers to read the textual information, many continued along with this form of behavior. On the other hand, the members of this group seemed much more engaged, and not nearly as bored as the hierarchical group participants.

Finally, the branching hyperdocument seemed to have offered its group members the appropriate freedom to navigate the knowledge space and enough structure to allow them to visit all the screens. The level of structure offered by this schema seemed to have benefited the students by holding their interest and focusing their attention on the task. Consequently, these observations, along with the data results, indicate that the branching hyperdocument group performed significantly better than the others because they were more engaged and focused (i.e., students did not become bored or distracted).

This finding also forms the basis for explaining the results associated with the branching group performing significantly better than the conventional group in the higher cognitive skills performance sub-test. It seems that an appropriate level of structure and
exploratory freedom may be required to promote higher cognitive skills. If the exploration space becomes too large, the opportunity for getting distracted and disoriented increases. This seems to be especially the case for the age group addressed by this study (early adolescence), since their attention span has been deemed to be notoriously short. This observation may also hold if the exploration space is too confining. Since the ability to focus and concentrate on semantic relationships are required to promote higher cognitive skills (Jonassen & Wang), a knowledge structure such as that offered by the branching schema may be demanded.

In considering the effects of the student's cognitive styles on performance results, no significant relationships could be established. More specifically, in examining the information processing styles of Active Experimentation and Reflective Observation, neither one could be significantly related to learner performance. Although not part of the study, an analysis of the information perception styles dimension (Concrete Experience and Abstract Conceptualization) yielded similarly non-significant results. Furthermore, no significant interaction was observed between the cognitive styles variable used in this study and the knowledge structure variable.

However, it is worthwhile to note that, when the research data were analyzed by gender (male or female), "almost" significant relationships at the .05 level were observed with male subjects for both the total (p < .07) and lower cognitive skills (p < .06)
performance scores. These inconclusive findings seem to add to the growing research literature that have consistently shown mixed results in relating cognitive style and learner performance (Paolucci & Wright, 1996).

This research study has clearly shown that hypermedia software, when appropriately structured for the learner, can be effectively used as learning systems to improve performance and achievement. Moreover, these learning systems provide an effective means for promoting and developing the learner's higher cognitive skills. Since no previous research had been conducted with adolescent students, this study addressed this need by conducting an empirical study with early adolescent students.

In general, the research results imply that teachers and educators need to be careful and pay close attention to how hypermedia software is applied in the curriculum. The technology has tremendous flexibility in providing dynamic learning environments for all types of students and needs. However, this flexibility seems to be a double-edged sword. It seems that if the hypermedia learning environment is designed to be too structured, many students will lose interest and the learning objectives may not be achieved. On the other hand, if this environment is too unstructured, many students will become confused and lose interest.

Thus, choosing the "right" structure seems to be the key in making effective use of hypermedia learning systems in the learning process. This is probably even more
important for young students (e.g., adolescents), who perhaps require more structure with their learning environments, and may need to be scaffolded throughout this early learning stage.

The notion of "scaffolding" the learning process seems to be particularly appropriate when using hypermedia. It may be an appropriate learning strategy to decrease the level of structure of the hypermedia learning system as the student matures. Culminating at the stage where the student himself or herself can actually develop their own hypermedia document and construct knowledge (as many constructivists advocate). The important point to be made here is that, this process will be highly dependent on the individual's skills and knowledge base, thus any strategy should be individualized. Teachers are encouraged to assess their students cognitive abilities (e.g., learning styles) in order to design instructional strategies for optimal learning.

Currently, the trend in many classrooms seems to be in letting most students create their own hypermedia documents. Thus, the above guidelines are rarely applied. Although these hypermedia projects may be deemed to be "cool" and fun by the students and teachers, very rarely is the question of whether knowledge of the domain has been acquired or learning has taken place.

Similarly, with the explosive growth and popularization of the Internet's World Wide Web, many teachers and educators (even at the elementary levels) are using these
highly hypermediated tools as learning environments. As this research study has shown, if the knowledge domain is too unstructured (as is definitely the case with the World Wide Web), learning becomes very difficult, especially for younger students. Therefore, structuring the World Wide Web, or any other similarly hypermediated technology (e.g., CD-ROMs), to meet the cognitive skills and knowledge base requirements of the learner, is critical.

In addition to the above observations, instructional systems designers and authors need to be keenly aware of the proper application of multimedia information. In authoring the HyperEcology software, it became very clear that by far the textual information was the key medium in the knowledge transfer design process. Although the sounds, images, and videos used in the hyperdocuments were chosen to enhance learning, most of this information was contained within the context of textual information base.

During the experiment, it soon became evident that the major focus of attention for the majority of the students were the sounds, images, and videos. Consequently, much textual information may not have been fully processed by these students. It seems that, although multimedia information may attract the attention of the learner (especially the younger ones), and perhaps enhance the learning of new knowledge, textual information still remains the key component in the transfer of knowledge with hypermedia. Thus, designers need to make sure that if multimedia information is used (as it should be) in authoring hypermedia, it is used to compel the learner to also read the text.
Finally, it is worthwhile to note that, quite a few students had difficulty concentrating and focusing on the task at hand. These individuals were often observed to be unable to sit still (of course, there were also many students that took the time to methodically read the screens and tried to process the information, regardless of the hyperdocument used). No technology will be effective in enhancing knowledge acquisition if attention and focus is not given. Thus, whether hypermedia can be effective for these students is questionable. On the contrary, unfortunately, it may even exacerbate this condition by providing an overly stimulating learning environment.

References


Table 1
Analysis of Covariance of Total Performance Scores

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*  p<.05
** p<.001

Table 2
Analysis of Covariance of Higher-Order Cognitive Skills Performance Scores

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*  p<.05
** p<.001

Table 3
Analysis of Covariance of Lower-Order Cognitive Skills Performance Scores

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**  p<.001