Information-Conveying Approaches and Cognitive Styles of Mental Modeling in a Hypermedia-Based Learning Environment

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The increasing spread of Internet technology has highlighted the need for a better understanding of the fundamental issues concerning human users in a virtual space. Despite the great degree of navigational freedom, however, not all hypermedia users have the capability to locate information or assimilate internal knowledge. Research findings suggest that this type of problem could be solved if users were able to hold a cognitive overview of the hypermedia structure. How a learner can acquire the correct structural knowledge of online information has become an important factor in learning performance in a hypermedia environment. Variables that might influence learners' abilities in structuring a cognitive overview, such as users' cognitive styles and the different ways of representing information, should be carefully taken into account. The results of this study show that the interactions between information representation approaches and learners' cognitive styles have significant effects on learners' performance in terms of structural knowledge and feelings of disorientation. Learners' performance could decline if a representational approach that contradicts their cognitive style is used. Finally, the results of the present study may apply only when the learner's knowledge level is in the introductory stage. It is not clear how and what type of cognitive styles, as well as information representation approaches, will affect the performance of advanced and expert learners.

Background

Learning is a process of reorganization of knowledge structure. Based on the concept of meaningful learning (Ausubel, 1963), in one way, learners structure knowledge to serve as a framework that helps them to associate new information with previous knowledge. As this framework becomes more complex, learners may in turn rely on this conceptual structure to filter important points from irrelevant ones. The acquisition of correct structural knowledge has become a critical issue in learning. Among other computer technologies, hypermedia has potential as a tool to mediate the structural knowledge of the target domain to learners. One of the theories about mind structure, the "mind as rhizome" (MAR) metaphor (Eco, 1984), hypothesizes that the human mind is organized like an underground rhizome. Hypermedia tangibly simulates the learning assumptions of this mind metaphor in that learners can filter, link, and search for new or existing information. These features have made hypermedia an ideal tool for supporting multilineal thinking and facilitating self-directed learning. Compared with novice users of a subject domain, expert users in the same domain are believed to possess a better knowledge structure that enables them to effectively solve problems. The learning strategy of externalizing experts' knowledge structures to provide "idiosyncratic" intellectual thinking (Schwen, Goodrum, & Dorsey, 1993) has been deemed a pragmatic way to empower learners. In essence, hypermedia opens new opportunities that permit developers to apply and test this learning strategy as never before. Through this technology, experts' knowledge structures are made visible and navigable for learners in a graphical or textual form. The success of learners in terms of acquiring expert knowledge structures thus increasingly depends on exploring interrelationships among an enormous number of linkages and ideas. Regardless of claims about the benefits of using hypermedia, however, Dias and Sousa (1997) have pointed out that the ordering of topics and points, as well as various traditional orientating devices such as overviews and summaries (usually

taken for granted in books and papers) are nonexistent in hypermedia. Without such orientating devices or narrative cues, and lacking a knowledge of hypermedia structures, users can barely determine where they are, what they want, and how to get there (Beasley, 1994; Tripp & Roby, 1990). These issues raise a number of questions. Is knowledge of the material's structure as important as scholars suggest? Can one attempt to represent the structure of a document cognitively, and if so, what form might the representation take?

Theoretical Framework

As hypermedia technology continues to evolve in the 21st century, engendering a myriad of applications, educators must seek the most appropriate ways to use this innovative media for solving problems. In the realm of education, hypermedia is a technology rooted in the cognitive procedure. It is presumed to be an associative information system intended to promote divergent thinking, to compare and contrast perspectives, to generate new inferences and interpretations, and to help novice learners acquire expert knowledge structures (Jonassen & Wang, 1993). Concerns have been expressed, however, that this information-rich environment does not, by design, help learners to a great extent in forming the assumed mental model of the content domain. Too few learners are skilled at regulating their learning. The majority of previous study results have indicated that using hypermedia might create the feeling of getting lost in the information space, which could further impede learning. Despite all of its promising features, there are several fundamental problems regarding hypermedia; it provides too few structural cues for some learners, and not all learners possess self-regulation ability. To identify the

causes of these problems, related structural issues for hypermedia and individual factors will be addressed and discussed.

Forms of Hypermedia Structures

According to Dillon (1994), researchers in this field have three distinct ways of regarding the structure in hypermedia. The first is Hammond and Allinson's (1989) suggestion. They posit that structure is a conveyor of context, which is a "naturally occurring structure to any subject matter that holds together the 'raw data' of that domain" (p. 107). It is thus an intrinsic structure that any document of a subject domain inherently has. Trigg and Suchman (1989) offer a second view. Structure for them is a "representation of convention." Authors or writers arrange the sequence and structure for the document according to their expectations. Finally, Conklin (1987) refers to structure as something "imposed on what is browsed by the reader." That is, it is the knowledge structure built by readers while reading the document. Dillon's classification is similar to that proposed by Korthauer and Koubek (1994). They categorize hypermedia as exhibiting three types of structures: inherent structure, explicit structure, and internal structure. Figure 1 presents the relationships between these structures and cognitive style.

As Hammond and Allinson's (1989) definition states, an inherent structure is a naturally occurring structure. Authors or writers have nothing to do with it, save to accept and represent this structure to readers in an understandable way. What researchers and designers need to be concerned with are the other two types of structures—explicit structure and internal structure. Both types of structures could have direct influences on learners' performance. Explicit structure uses
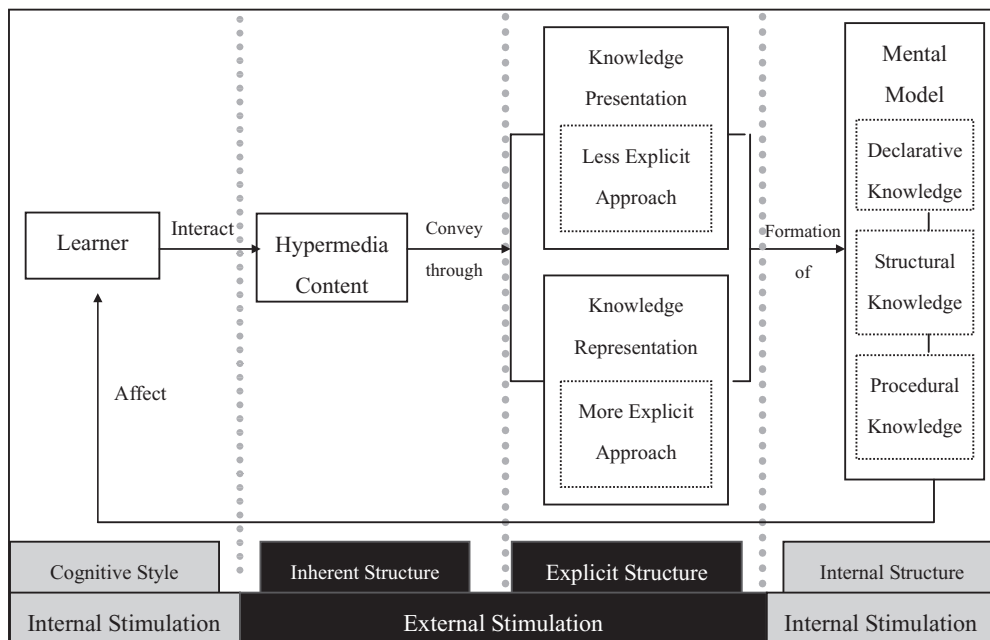

FIG. 1. The relationships between inherent structure, explicit structure, internal structure and cognitive style.

two approaches to convey information: the obvious navigation link and the navigation aid. The obvious navigation link results when authors or experts of the materials attempt to anticipate the most useful pathways through the inherent structure, and develop learning paths accordingly. This can be viewed as the form of knowledge-presentation system recommended by Nelson and Palumbo (1992) and Reed, Ayersman, and Liu (1996). They argue that instructional hypermedia systems could be divided into three forms: a knowledge-presentation system, a knowledge-representation system, and a knowledge-construction system. The knowledge-presentation system is the arrangement of nodes and associative links. The emphasis in this system is on "tours" to assure that the learner has viewed the critical information. Examples such as hierarchical structure and associative structure can commonly be seen in many hypermedia-based instructions. While the navigation link is the means by which authors try to explicitly convey structural information to their readers, such links are not as explicit as navigational aids. Because of this, in the discussion in this study, the approach relying on hyperlinks will be referred to as the "less explicit" approach.

As for the navigational aid, it can be viewed as a type of knowledge-representation system (Nelson & Palumbo, 1992; Reed et al., 1996). The designer provides maps or graphical navigational aids to convey the structure of the material to the learner. In this system, relationships between concepts are made explicit and are represented visually. Learners can therefore understand more easily how know-ledge bits in the system are interconnected and how that knowledge can be integrated into the learner's previous knowledge. A navigational aid such as a concept map graphically demonstrates to readers the relationships between links. For the purposes of the present study, this type of navigational aid will be referred to as the "more explicit" approach.

Finally, an internal structure may be compared to Conklin's (1987) concept of the knowledge structures of users who are experienced in the content domain. The internal structure can be seen as a type of knowledge-construction system (Reed et al., 1996). In the following discussion, the term "mental model" will be used to refer to internal structure.

Mental Models

The concept of the mental model was first proposed in the 1940s by Craik (1943) as "a 'small-scale model' of external reality" (p.57) carried in the user's head to react to or anticipate future states that have never been experienced. In other words, it is an internal "qualitative simulation" model (Borgman, 1986) that enables the user to make inferences in complex situations. Ever since, the term *mental models* has been explicated in various ways within the field of cognitive psychology. In general, most scholars agree with the assumption that mental models might continually evolve as situations change or as individuals acquire more knowledge. By this cognitive mechanism, users construct the structures and internal relationships of a to-be-learned system during the process of interacting with it (Dimitroff, 1992).

The relative study theme of the mental model has fast manifested itself as one of the major theoretical frameworks of HCI research. Norman (1988) provided a well-known definition of mental models in the context of HCI: "*Mental model*, the model people have of themselves, others, the environment, and the things with which they interact. People form mental models through experience, training and instruction" (p.17). Different from conceptual models in which the designer creates a metastructure to explicitly facilitate the user's information processing, mental models are users' interpretive representations which drive their behavior internally. Numerous studies have attempted to prove how users might apply mental models to interact with systems. While the findings report that the models users form are usually vague or obscure (Bainbridge, 1992; Wilson & Rutherford, 1989; Norman, 1983), Preece et al. (1994) indicated two types of mental models often employed by users: structural models and functional models. Structural models are models of *how-it-works*, while functional models are models of *how-to-use-it*.

Structural models are the schematic forms of component parts of devices viewed in a context-independent manner. This type of model mainly provides a basis for regulating the internalization process of system images. Functional models, or the so-called "task-action mapping models" (Young, 1983), in contrast, represent how the device works in a context-dependent situation. The former can be characterized in terms of symbolic representations and subsymbolic representations (Eysenck & Keane, 1990). The latter is the knowledge gained from the scenarios of users trying out the device for different tasks. It might thus be greatly affected by users' previous experiences of a similar domain. Although the debate continues about whether people mainly think analogically or propositionally, it seems likely that they use both approaches to complement each other. That is, symbolic representations are structured and stored in a combination of analogical and propositional modes (Johnson-Laird, 1983, 1988). Additionally, subsymbolic representations (distributed representations) work as an implicit network to wire these emergent symbolic nodes together. To that extent, structural models can be matched to declarative knowledge and structural knowledge; functional models are identical to procedural knowledge. These three knowledge types will be further discussed below.

The Development Stages of Mental Models

Scholars use different terms to describe the development of mental models, though these terms all portray similar phenomena (see Table 1). In Royer, Cisero, and Carlo's (1993) article, the authors revived a development view of knowledge construction that was proposed by Anderson in 1982. This knowledge-development theory originated from the observations of Fitts in 1964. Fitts stated that skill acquisition follows a three-stage process: a cognitive stage, an associative stage, and an autonomous stage. This theory was

TABLE 1. Scholars' visions of the development stages of mental models.

Fitts (1964)	Cognitive stage	Associative stage	Autonomous stage
Rumelhart (1980); Driscoll (1993)	Schema		Schemata
Anderson (1982)	Declarative knowledge	Knowledge compilation	Procedural knowledge
van Dijk & Kintsch (1983)	Microstructures	Macrostructure formation	Macrostructural regularity
Frick (1997); Jonassen, Beissner, &Yacci (1993)	Knowing that	Knowing that one (Knowing why)	Knowing how
Jonassen, Beissner, & Yacci (1993)	Declarative knowledge	Structural knowledge	Procedural knowledge

elaborated in 1982 by Anderson, who associated it with his ACT production system of human cognition. The concept of learning by doing and a scheme for assessing mental models which Anderson argued should be embedded within a theory of knowledge development are described as follows:

The declarative-knowledge stage. The learner receives the instruction for a set of facts relevant to the execution of a particular skill. These facts represent general procedures to generate behaviors. They are interpreted and stored in the learner's declarative memory in the form of statements. This stage corresponds to Fitts' cognitive stage. The learner's working memory load is especially high in this stage. In addition, to continue rehearsing these facts through verbal mediation, the learner must keep the learning goal and the general problem-solving strategy in working memory at the same time.

The knowledge-compilation stage. With practice, the factual information acquired in the declarative stage is gradually transformed into a procedural form in which learners may apply minimal conscious reasoning activity. This gradual process is called the *knowledge-compilation stage*, which is a transition stage between the declarative stage and the procedural stage. This stage corresponds to Fitts' associative stage.

The procedural-knowledge stage. After the factual knowledge has been translated into a series of procedures that can be applied automatically without other interpretive activities, tuning steps follow to help learners apply this knowledge more appropriately. Two learning activities are needed for this purpose: the speedup process and the strengthening process. The speedup process is "a continuation of the knowledge compilation stage wherein separate cognitive activities continue to compile, thereby speeding up their actions" (Royer et al., 1993, p. 206). The strengthening process "gradually eliminates productions that have general utility in task performance and weakens productions that may interfere with skilled performance" (Royer et al., p. 206).

In general, these three stages of knowledge development could also be termed respectively by Jonassen, Bessner, and Yacci's designations (1993): *knowing that*, *knowing why*, and *knowing how*. The knowledge types *knowing that* and *knowing how* are sometimes also correspondingly termed

schema and *schemata* (Driscoll, 1993; Rumelhart & Ortony, 1977). Essential to a schema (Bartlett, 1932) for an entity or an event is a collection of information or discrete concepts which help us to identify that entity or event. Schemata are packets of schema that are composed of the interrelationships among schemas. Without the interrelationships, schemas cannot form schemata.

Structuring knowledge: The core of mental models. Thus, in order to form the schemata, learners need to acquire the knowledge of the interrelationships between schemas. That is, in order to shift the knowledge from *knowing that* to *knowing how*, learners have to first gain *knowing why* (knowledge compilation; Jonassen et al., 1993). Figure 2 displays this formation process for different development stages of mental models. Structural knowledge serves as the core stage during this process.

Koubek and Salvendy (1991) define structural knowledge as the structure of interrelationships between concepts and procedures (elements) in a particular domain, organized into a unified body of knowledge. These concepts or elements can be declarative or procedural. In this definition, elements are either declarative or procedural knowledge in nature and are linked by structural knowledge. Jonassen et al. (1993) point out that structural knowledge is the knowledge that learners may acquire in the knowledge-compilation stage: "Structural knowledge mediates the translation of declarative into procedural knowledge and facilitates the application of procedural knowledge" (p. 4).

Structural knowledge represents how concepts for a content domain are organized and interrelated within the learner's mind. This argument is similar to Quillian's (1969) semantic model of human memory. According to Quillian, knowledge is a network of interrelated concepts. Knowledge structure is represented in terms of nodes and links. In the discussions of other researchers (Reynolds & Dansereau, 1990; Mahler, Hoz, Fischl, Tov-ly, & Lernau, 1991; Norman & Rumelhart, 1975), structural knowledge is sometimes referred to as a "cognitive map" or "cognitive structure". An expert's structural knowledge has characteristics which differ from a novice's structural knowledge. Experts consolidate or "chunk" information, resulting in a highly efficient format. Their knowledge structure is more stable and well-organized in terms of memory than that of novices (Schvaneveldt et al., 1985). An expert is said to proficiently utilize this highly organized memory structure to solve
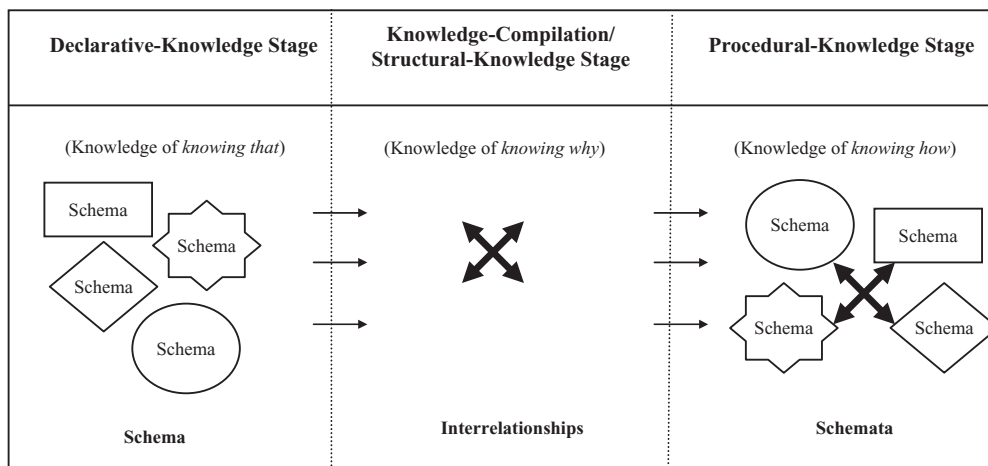
Declarative-Knowledge Stage	Knowledge-Compilation/ Structural-Knowledge Stage	Procedural-Knowledge Stage
(Knowledge of *knowing that*)	(Knowledge of *knowing why*)	(Knowledge of *knowing how*)
Schema Schema Schema Schema		Schema Schema Schema Schema
Schema	**Interrelationships**	**Schemata**

FIG. 2.   The development stages of mental models.

problems. It is thus considered helpful to externally map expert knowledge structures for novices and to establish a clearly articulated parallel between the user's tasks and the program design.

Hypermedia appears to be an appropriate scaffolding tool for those tasks in which an expert's conceptual framework of a subject domain is visually presented to learners. However, the positions of concepts in learners' minds are not fixed, but instead dynamically change as their knowledge increases. This may entail different cognitive needs during the mental-development stage. Some have recognized that learners will take longer to achieve the procedural-knowledge stage than the two earlier stages (Reed et al., 1996). Learners need to practice their declarative and structural knowledge in different problematic situations to form procedural knowledge. This knowledge, in turn, helps learners to adjust their existing structural knowledge. This assumption is similar to van Dijk and Kintsch's theory of discourse comprehension (van Dijk & Kintsch, 1983). This theory was developed to illustrate the linguist's view of how people comprehend discourse. It places great emphasis on the text structure for skilled reading. van Dijk and Kintsch believe that reading involves the development of schematic analysis of the material (microstructures), the subsequent macrostructure formation, and macrostructure regularity (superstructures). They suggested that readers should first concentrate on building the first two levels of structures, and when these have been developed to a great extent, then they may work on the third. In this case, the microstructure formation is similar to declarative knowledge, and the macrostructure formation is similar to structural knowledge. Dimitroff (1992) suggested a similar concept in that, without correct mental models acting as a metastructure, users might face difficulties, even if the system provides cues to compensate for their deficiencies in the tasks of information retrieval.

Instruction should first facilitate for learners the acquisition of accurate declarative and structural knowledge. Beyond the consideration of the external aspect, as with the interface or information issue, it is suspected that learners'

cognitive characteristics could be highly related to the success rate for acquiring structural knowledge. Indeed, the acquisition of structural knowledge is an important issue in hypermedia learning.

Internal Stimulation: Cognitive Style

To acquire new knowledge, learners need to involve key cognitive processes such as perception, imagery, organization, and elaboration (Glynn, Yeany, & Britton, 1991). Instead of being passive receivers, learners will selectively look for information according to their prior knowledge and expectations. In most situations, learners keep directing their efforts to make sense of the incoming information by assimilating it into their existing knowledge framework. As a result, no two learners could possibly acquire the same information and interpret it identically. This interpretation procedure is highly subjective and is predominated by learners' cognitive differences (Riding & Glass, 1997; Chen & Macredie, 2002). Research findings support this notion that individual cognitive differences affect performance results among adults (Davidson, Savenye, & Orr, 1992; Ford, Wilson, Foster, Ellis, & Spink, 2002). Understanding these differences can help instructors cope with the variations in performance exhibited by their students.

Several scholars have investigated the effects of individual differences, especially in the context of computer-based learning. A number of individual elements that generate critical influences on learning were found. They are learners' motivation (McAleese, 1993), cognitive style (Ellis, Ford, & Wood, 1993; Jonassen & Wang, 1993), age (Heller, 1990), domain-specific knowledge (Egan, 1988), and experience using computers (Rhee, 1993). Among the above elements, cognitive style is arguably one of the most important factors that might affect learners' performance, especially in a hypermedia environment (Andris & Stueber, 1994; Ayersamn, 1993; Chang, 1995; Leader & Klein, 1996).

The cognitive style in this study is from the notable works conducted by Witkin (1950) and Pask (1979). An increasing

diversity of cognitive-style studies has been seen in recent years. These extend from information seeking in library and information systems (Spink, Wilson, Ford, Foster, & Ellis, 2002), problem solving and decision making (Issa, 2002; Spicer & Sadler-Smith, 2000), cultural differences and learning (Graff, Davies, & McNorton, 2004; Sternberg & Zhang, 2001), and virtual environments (Ford, 2000). The major focus of the present study is the effect of cognitive style on mental modeling.

Learning style versus cognitive style. In the literature, learning style and cognitive style have been discussed synonymously, though they actually have different meanings. Keefe (1987) indicated that learning styles have cognitive, affective, and physiological traits. They are relatively stable predictors for how a learner gains knowledge using his/her preferred approach. Cognitive style refers to a learner's habitual mode of information-processing being manifestly reflected in his/her perceptual ability and personality (Dufresne & Turcotte, 1997; Mammar & Bernard, 2002). Although the characterization and operationalization of this important metacomponent remain in dispute (Tucker & Warr, 1996; Riding & Cheema, 1991), the present study adopts what Riding and Cheema proposed, i.e., a combination of the structure and process views. That is to say, cognitive styles are relatively stable, but they are also in a state of flux as learners gain more experience or knowledge from the instructional materials. The status of the learner's cognitive style is continually being modified. Learners' performance might eventually equal out regardless of which type of cognitive style each learner possesses. It could be just a matter of time. Yet, what needs to be determined is how we can accelerate the process of learning for all subjects, and by what means.

Field dependence and field independence. In this study, cognitive style will be examined within the dimension of field dependence/independence (FDI) (Witkin & Asch, 1948), which has been identified equivalently as Pask's (1979) Holistic/Serialist styles (Jonassen & Grabowski, 1993). The reason for choosing this dimension to investigate is that it has a profound influence on learning performance in a nonlinear hypermedia environment, where an ability to structure and to restructure data is of central importance. Specifically, FDI implicitly conditions the development of operative schemata as well as learners' overall cognitive structuring (Robertson, 1990; Fitzgerald & Semrau, 1998). This dimension differentiates the tendency of an individual to structure and analyze incoming information. Field-dependent learners might adopt a global strategy and demand information with more explicit cues. On the other hand, field-independent learners tend to employ an analytical approach, and are able to extract relevant cues inherent in the field (Chen & Macredie, 2002; Antonietti, Ignazi & Perego, 2000). In other words, field-dependent learners are likely to process information passively by operating an external reference, as opposed to the "inner

directedness" of field-independent learners, who might prefer actively imposing their own structure (Ford et al., 2002). As a result, compared to field-independent learners, field-dependent individuals are more likely to have greater difficulty learning when the learner him/herself is required to provide organization as an aid to learning, as is required in a nonlinear environment. Hence, information systems should be designed to accommodate the different preferences of learners with different cognitive styles (Chen, Czerwinski, & Macredie, 2000; Leader & Klein, 1996).

External Stimulation for Hypermedia

From the learner's perspective, there are two stages of the learning process in hypermedia-based instruction: information seeking and knowledge acquisition (Chou & Lin, 1998). There are two common techniques to facilitate learners' information-seeking behavior in a two-dimensional hypermedia system (Wilson & Jonassen, 1989; Jonassen et al., 1993). The first technique is to use the hyperlink organization so that, to some degree, information is implicitly transmitted to learners. This technique is similar to the "less explicit" approach discussed previously. The second technique is considered similar to the "more explicit" approach defined earlier in this article. This technique uses graphical organization, and explicitly conveys important information, such as the structure information, to learners. Through these two techniques, learners might be able to integrate the new knowledge with existing knowledge. However, whether learners could benefit from a less explicit approach or a more explicit approach remains questionable.

Less explicit approach. Generally, there are four types of less explicit approaches that can often be seen in hypermedia (Shneiderman & Kearsley, 1989; Jonassen, 1990):

- Hierarchical structure
- Hierarchical-associative structure
- Associative structure
- Networking structure

The less explicit approach is an important factor in learners' performance in hypermedia. Parunak (1989) and Batra, Bishu, and Donohue (1993) both suggest that hyperlink structure may affect an individual's ability to locate and extract information. McDonald, Paap, and McDonald (1990) emphasize the importance of information structures when organizing a hypermedia database. According to the literature, learners in a hypermedia environment prefer hierarchical structures and hierarchical-associative structures over other types of less explicit approaches used in hypertext-based instruction (Edwards & Hardman, 1989; Lin, 1995). Users in the networking structure context not only need to focus on the tasks and search for the answers, but also have to figure out where they are in the database (McDonald &

Stevenson, 1996; Simpson & McKnight, 1990). Learning performance is reduced due to the cognitive overhead.

However, a well-structured format may not always be an appropriate choice in all online learning situations. As learners become more experienced, constrained linking within hierarchical structures may delay their browsing speed, since each node at one level can access nodes only directly above or below. One solution that can be considered when determining the basic design format of hypermedia material is a hybrid structure (Gordon & Lewis, 1992). This type of structure possesses the basic characteristics of a hierarchical structure and direct access to other associative nodes, so as to benefit both novice and expert users. That is, all readers would browse certain information in a particular order, yet they could still directly access related information. The linear base form (hierarchical structure) can serve as a basis to avoid disorientation and cognitive overload, while the associative feature can speed the browsing process by means of direct links to the necessary information. For these attributes, the hierarchical-associative structure has been chosen for the present study.

More explicit approach. Without access to cues for conceptual frameworks, hypermedia learners could become confused or lost as they navigate large networks (Chou & Lin, 1998; Tripp & Roby, 1990). The navigational problem has been a critical issue for online instruction (Batra et al., 1993; Hammond, 1993; Smith & Wilson, 1993). Three methods have been employed to tackle this problem (Korthauer & Koubek, 1994, p. 376):

A. Structure the hypertext database in such a manner that it is "transparent" to the user;

B. Provide an effective interface that guides the user through the hypertext database;

C. Develop a well-structured database with an efficient interface (a combination of A and B).

Method A can be viewed as an example of the less explicit approach, which is discussed above. Method B suggests that a good interface design is needed to facilitate learning. Many types of visual-cue studies have been developed to meet this goal, such as landmark, icon, or metaphor studies. It has been found that information visualization can assist subjects in developing a more robust mental model of the interrelationships to be found in the content (Wenger & Payne, 1994). In addition, several researchers (Gaines & Shaw, 1993; McDonald & Stevenson, 1999) have expressed the belief that users in nonlinear environments need visual aids from their environment in order to alleviate navigational problems, such as the disorientation problem.

Method C is developed from Method A, but represents information in a visual manner. Various terms such as *spatial hypertext* (Shipman & Marshall, 1999), *horizontal navigation* (Brusilovsky & Rizzo, 2002), and *concept map* (Nielsen, 1990; Novak, 2000) have been used to describe a similar concept. Among them, *concept map* is the term that has been widely adopted by researchers.

Concept maps are maps that display interconnectedness in the form of a directed graph. Based on the mental representation formed by the experts, information is presented in a graphic format that externalizes spatial relations among concepts (Dias & Sousa, 1997; McClellan, Harvel, Velmurugan, Borkar, & Scheibe, 2004). A concept map can be considered the "official view of the domain," usually created by experts (Mahler et al., 1991). In hypermedia-based instructions, concept maps are presented as templates to facilitate the novices' acquisition of expert knowledge structures. They consist of two- or three-dimensional node-link networks that visually depict numerous interrelated and important concepts (Ferry, Hedberg, & Harper, 1999). This approach has been categorized by Jonassen et al. (1993) as an organizing strategy that helps the learner to construct or reorganize his/her knowledge structure by showing how concepts relate to each other. Such an activity strengthens the associative links between concepts in long-term memory. Users can depend on concept maps, and can access multimedia materials through indexing mechanisms. In general, concept maps are used as stand-alone documents or are embedded as interactive pictures in active documents (Gaines & Shaw, 1993).

Related Studies

The results of previous studies on whether a less explicit approach or a more explicit approach can better strengthen learners' performances in a hypermedia environment have been inconclusive to date. Wright and Lickorish (1989) asked subjects to search hypertext databases using either a map or an index. No significant differences were found. Similarly, Gordon and Lewis (1992) measured the effects of maps on hypermedia learning. Neither constrained networking nor maps created the expected results when compared with the other four treatments. Jonassen and Wang (1993) divided subjects into three groups—control, pop-up window, and map—to study a hypertext knowledge base. This study did not produce any significant results in terms of relationship, proximity, or analogies. Stanton, Taylor, and Tweedie (1992) investigated the use of a map for the formation of system mental models. The no-map group significantly outperformed subjects in the with-map group.

Two issues are worth pointing out here. First, some tasks in the studies above were information seeking or information retrieval. Successful performance in these types of tasks "[depends] on the reader's ability to abstract and retain information about the structure of the information, in order to quickly locate and efficiently integrate that information" (Wenger & Payne, 1994, p. 226). Also, if the task did not involve a learning issue, but was meant only to locate specific information within the database, the question arises as to whether subjects would still be able to form the correct mental model, since they all concentrated on finding specific information and had no time to study the whole content

(Jonassen & Wang, 1993). Second, some of the above studies were not designed to let subjects directly access information from the map device. Subjects were only oriented by the map; they did not navigate on the map. In such a situation, subjects may need to remember the map while having to complete tasks at the same time. This additional function does not serve as a navigational aid to enhance learning, but rather places more cognitive load on subjects (Spiro & Jehng, 1990). For these reasons, subjects' characteristics (such as cognitive styles that might influence users in retaining or abstracting hypertext structures), the learning tasks, and methods for using maps were reconsidered by the present study design.

In contrast to the above studies, many researchers (Novak, 2002, 2004; Quinn, Mintzes, & Laws, 2004) have endorsed the effectiveness of concept maps for enhancing learners' performance in the hypermedia environment. Chou and Lin (1998) measured the effects of the local map and the global map. They found that the global-map group showed higher searching ability and took fewer steps than the other groups. The global-map group also formed better mental models than the local-map group. Similar to Stanton, Taylor, and Tweedie's (1992) study, Reynolds, Patterson, Skaggs, and Dansereau's (1991) study assessed the effects of *hotword* and *hypermap* browsing devices on learners' recall, reference time, and accuracy. The hotword group reported significantly higher levels of frustration and confusion. Subjects were found to favor the map-browsing device. Sturm & Rankin-Erickson (2002) conducted an empirical study to measure students' writing of descriptive essays using one of three systems: no-map, hand-map, and computer-map support. Significant positive attitudes toward the computer-map method were found among subjects.

Summary

To summarize, many factors, such as interfaces and those cognitive characteristics that the learners bring with them, will influence learning behavior in human-computer interaction processes. As Vaske and Grantham (1990) suggest, the difficulties of learning in a computer-based environment are caused by the discrepancies between (a) individual mental representations and cognitive styles, and (b) the given operations of the scope of action prescribed by the software (Vaske & Grantham). In other words, the hypermedia environment, augmenting the linear sequencing of past systems, permits a learner to explore content at his/her own pace and volition. The learning results may thus vary greatly because of the differences in the content exposure (interface effects, e.g., hyperlink, concept map) and learning patterns (cognitive styles) of users. Figure 3 shows the conceptual framework of the present study.

The research problems of this study, based on the literature review above, are as follows:

1. Will different information conveying approaches (less/more explicit approaches) and/or learners' cognitive styles (field dependent/field independent) affect learners' structural knowledge?
2. Will different information conveying approaches (less/more explicit approaches) and learners' cognitive styles (field dependent/field independent) affect learners' feelings of disorientation?
3. Will different information conveying approaches, learners' cognitive styles, learners' structural knowledge, and/or the interactions of these three correlate to learners' feelings of disorientation?

Method

Subjects

The subjects in this experimental study were students selected from a university in the mid-eastern United States. Subjects' ages ranged from 19 to 45. A two-stage filtering procedure was administered to identify the most appropriate subjects from an initial sample of 106 students at the beginning of this study. Subjects who were familiar with the domain of the experiment contents were pre-excluded according to their replies on the computer-background questions. The cognitive styles of the 68 qualifying subjects were identified by a Group Embedded Figures Test (GEFT). These subjects were then randomly assigned to two groups: the less explicit (LE) group and the more explicit (ME) group. Each group included 34 subjects, with an equal number of field-dependent (FD) and field-independent (FI) subjects, giving four categories: LE/FD, LE/FI, ME/FD, and ME/FI.
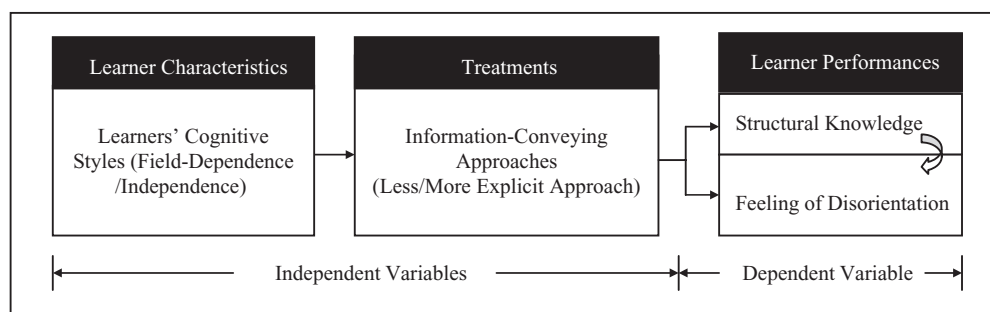

FIG. 3.   Conceptual model of this study.

Instruments

Group embedded figures test. The Group Embedded Figures Test (Witkin, Oltman, Paskin, & Karp, 1971) was administered to determine subjects' cognitive styles: field dependent or field independent. The GEFT is the group form of the original individually-administered Embedded Figures Test (Witkin & Moore, 1974). Researchers have demonstrated that the GEFT can be used as a cognitive measure with nonnative English speakers of various cultural backgrounds (Abraham, 1983; Hansen-Strain, 1989; Jamieson, 1992; Mshelia & Lapidus, 1990). In broader terms, the GEFT distinguishes between a global versus an analytical dimension of cognitive style. It measures the ability to identify a simple figure within a larger complex figure that has been designed to obscure and embed the simple one.

The reliability of the GEFT has been shown to be relatively high. The manual for the GEFT reported a reliability estimate of .82 (Witkin et al., 1971). Strawitz (1984) found the reliability of the GEFT to be .86, and Lawson (1983) reported a reliability of .88. When the GEFT was used, subjects were asked to trace 18 simple items embedded within a complex figure within 10 minutes. The subjects' scores could range from 0 to 18. Most of the research studies had a cut point of 9. Subjects who scored from 0 to 9 were classified as field-dependent (Bertini, 1986; Doebler & Eicke, 1979); subjects who scored from 10 to 18 were classified as field-independent. This approach of having a cut point of 9 could help researchers who are short of funding to gain enough subjects, in order to thereby increase their chances to obtain statistically significant results. However, this approach also increases the risk of a lack of consideration of the effects caused by people whose GEFT scores fall in the middle of this spectrum. To solve this problem, some researchers have used only the extreme scores to represent field-dependent and field-independent subjects (Adejeumo, 1983; Annis, 1979; Massoumian-Zavareh, 1986). Other researchers included a third intermediate classification between field-dependent and field-independent people (MacNeil, 1980; Stanton & Baber, 1992). Both approaches might help researchers to identify extremely field-dependent and field-independent people, but could also increase the difficulty of carrying out the present study. After considering all the benefits and drawbacks of the cut-point approaches for the GEFT (Bertini, 1986; MacNeil; Stanton & Baber), an eclectic approach was applied in this study to identify field dependence/independence. Subjects' GEFT scores of 11–18 indicated higher field independence, while subjects' GEFT scores of 0–8 reflected higher field dependence. The posttest data from subjects whose GEFT scores were 9 or 10 was taken away and was not used for further statistical analysis. The posttest data from a total of eight subjects was thus accordingly removed before the beginning of the statistical analysis. Gender difference in the development of field dependence/independence is considered so small as to not be statistically significant (Davis & Cochran, 1989), and thus was not considered as a study issue.

Instructional materials. The topic of this Web-based instruction was building a homepage. The content and categories of this topic were adopted from the Indiana University "Webmaster" Web site (http://webmaster.indiana.edu/). This website provides information for those who wish to build or maintain a Web page by themselves.

After filtering out some unnecessary categories, the remaining categories and their subcategories were rearranged into a hierarchical-associative structure. Thirty-five subcategories were included under these three main categories: getting an account, getting the tools, and getting started. Without changing the original meaning, the related information extracted from the "Webmaster" site was added to this structure to constitute a total of 56 Web pages of online instructional materials for this study.

Interface layout. Two different interfaces were developed to distribute these online instructional materials: the less explicit (LE) approach and the more explicit (ME) approach (see Appendix). Subjects in the LE group used hyperlinks to read through the learning content. These hyperlinks were arranged in a hierarchical-associative manner that was assumed to be salient to the subjects. Subjects in this group had to browse through the whole set of instructions and extract the overall relationships embedded between concepts by themselves.

Unlike subjects in the LE group, subjects in the ME group were provided with a navigational device: an interactive concept map. This concept map was built with the same content and structure as was used in the LE group, but it graphically externalized the content structure and overall relationships between nodes. In the ME group, the browser window was divided into two parts, using the frame function. The interactive concept map showing the entire hierarchical-associative knowledge structure remained consistently above the frame throughout the process. When subjects clicked on any node on this concept map, the relevant information would be displayed on the window under the frame. There was no hyperlink embedded inside the displayed information, such as there was for the LE group. Instead, in this approach these hyperlinks were disabled and replaced by red text.

Performance Posttest and Questionnaire

Structural-knowledge posttest. The framework of the structural-knowledge posttest was adopted and modified from Antico's (1995) study. The instrument was composed of a three-part test—concept recall, structural knowledge, and content—to protect the integrity of the structural-knowledge test data. The design of the "concept recall" part of the test was intended to help subjects concentrate on and memorize the concepts that they had just read about in the hypermedia-based instruction. Subjects did not get any score from this part. The "structural knowledge" part tests the students' recall of how concepts in the instructional materials are related to one another. This test asked subjects to identify

CONCEPT		CONCEPT	
Softserve	....	Telnet	__A__
	A) .... includes		
	B) .... is part of		
	C) .... neither includes nor is part of		

FIG. 4.   Sample question for structural-knowledge posttest.

one of three possible descriptions that correctly described the specific relationship between two given concept pairs (see Figure 4).

In all, there were thirty pairs of concepts presented in random order. Ten pairs presented one concept that *includes* the other, and another ten pairs presented a concept that *is part of* the other, thus covering the two types of hierarchical relationships. A final ten pairs presented one concept that *neither includes nor is part of* the other, thus covering cluster relationships.

Finally, the "Content" part measured the student's knowledge of building homepage concepts. Questions required the student to know the meanings of concepts and how those concepts can be applied in various homepage construction problems and situations. This test included ten randomly ordered items in which subjects had to choose the correct one of four responses.

This method was considered more direct and more easily managed than the word-association method which relies on the overlap of semantic meanings of words to indicate a degree of relatedness. While the word-association method is a reliable method, it has inherent problems. One is that it might become cumbersome once the number of measuring concepts increases. The number of possible comparisons for a set of 35 concepts, as in this study, for example, is 595 $((N \times (N-1)/2)$ (Jonassen, Beissner, & Yacci, 1993; Preece, 1976). The other problem is that word-association data alone might not reveal whether the learner has developed an understanding of the nature of the relationship between concepts or is merely aware that two concepts are related in some way and to some degree (Driscoll, 1985). Other common methods, such as sorting cards or drawing cognitive maps, were considered unfair for the LE group, since the ME group had been provided with a concept map as the navigational device.

The measurement properties of this instrument were tested. The results revealed apparent content validity ($>.4$, 78.672%) and a Cronbach's α reliability coefficient of 0.91.

Disorientation questionnaire. The disorientation questionnaire is a self-reporting instrument adopted from Beasley's 1994 study. To answer this questionnaire, subjects are required to circle a number on a 7-point Likert scale to indicate their feelings about this instructional material. The highest score indicates the most disorientation. During data analysis, the subjects' disorientation scores were correlated with other

independent variables (cognitive style and the information-conveying approach) and the scores from the structural-knowledge posttest.

Procedure

According to the assigned groups and individual cognitive styles, the specific tutorial Web pages (LE version or ME version) were loaded onto the subjects' screens. Subjects were given five minutes to practice and master the tutorial Web pages. With a consistent interface layout (structure and linking method) like that of the "Building A Homepage" experimental site, the tutorial Web page replaced the content about building a personal homepage with the chapter "Americans' Life, Leisure, and Culture (1840–1860)" from the book *The Enduring Vision: a History of the American People* (Boyer et al., 1996). During this tutorial session, subjects were not allowed to move to the "'Building a Homepage" site until they were completely familiar with the learning environment and were able to access information without problems. After this 5-minute tutorial session, subjects were required to spend at least 50 minutes (or even longer, depending on their wishes) studying the "Building a Homepage" Web site. Note-taking was allowed during reading, but these notes could be used only to help the subjects' memorize the instructional content. Notes could not be used when answering the questions on the later posttest. After the study session, subjects were required to complete the three-part posttest and the disorientation questionnaire. The average time to complete the posttest and the questionnaire was 25 minutes.

Findings and Discussion

The primary question of this study was which students with different cognitive styles who used either an LE approach or an ME approach would demonstrate better results with regard to their structural knowledge and feelings of disorientation. Also of interest was the correlation between structural knowledge and disorientation. This was a completely randomized factorial design composed of two treatments. Each treatment included two levels. Multiple ANOVA analyses were conducted to examine the hypotheses in this study. The level of significance (alpha) was set at .05 for all hypothesis tests. When appropriate, main effects, simple main effects, treatment-contrast interactions, and

TABLE 2. The diagram for 2 × 2 CRF-pq design.

	Cognitive style	Less Explicit Approach (hyperlink)	Mean (Group Embedded Figures Test)	More Explicit Approach (concept map)	Mean (Group Embedded Figures Test)
N	Field dependent	17	4.8	16	6.3
	Field independent	17	16.9	18	14.7
	Total	34		34	

contrast-contrast interactions were evaluated. Accordingly, Pearson correlation coefficients were used to determine the interaction relationships among cognitive styles (FD/FI), information-conveying approaches (LE/ME), structural knowledge, and feelings of disorientation. Correlation hypotheses were tested by either the ratio or interval of the mean squares of each source of variation variable to the mean square for the residual. The level of significant correlation was set at .01 (two-tailed). Table 2 shows how the data are laid out for this analysis.

To address the research problems, the following questions were developed to test the hypotheses:

Research Problem I

Will different information-conveying approaches (the less explicit and more explicit approaches) and/or learners' cognitive styles (field dependent/field independent) affect learners' structural knowledge?

Research questions for Problem I.

- Is a subject's structural knowledge significantly influenced by his/her use of a less explicit approach compared with a more explicit approach?
- Is a subject's structural knowledge significantly influenced by his/her cognitive style (field dependent/field independent)?
- Is a subject's structural knowledge significantly influenced by the interaction between the less explicit and more explicit approaches and the subject's cognitive style (field dependent/field independent)?

After examining the data for the research questions, the analysis of variance for structural knowledge that reflects the design using the concept map was not found to be significantly superior to the design using the hierarchical-associative hyperlink to acquire structural knowledge (.129, $\alpha > .05$). Similarly, the statistical results did not show that cognitive style significantly affected the ability to acquire structural knowledge (.109, $\alpha > .05$). However, an interaction effect was found between the two independent variables, which corresponded to the learners' structural knowledge (.011, $\alpha < .05$) (Figure 5). FD subjects' performance regarding structural knowledge was profoundly affected by the given treatments (.004, $\alpha < .025$); the concept map substantially increased the FD subjects' structuring ability compared to the

FD subjects who used the hierarchical-associative hyperlink. In contrast, the FI subjects seemed to perform equally well in the acquisition of structural knowledge no matter which type of treatment they received (.467, $\alpha > .025$). Comparing FD subjects' and FI subjects' performance in the LE group, the FI subjects gained significantly higher structural knowledge than the FD subjects (.005, $\alpha < .025$). This result suggests that FI subjects possess better cognitive abilities to manage the information structuring process than FD subjects. In fact, the group with the FI subjects who used the LE approach returned the highest score on structural knowledge of all four groups.

In a hypothesis comparing the effects of using the ME approach, interestingly, the FI subjects did not score higher on structural knowledge than the FD subjects, as was expected (.638, $\alpha > .025$). Instead, the FI subjects performed more poorly $\mu = 25.11$) than the FD subjects ($\mu = 26.31$) in the structural knowledge posttest. That is, FI learners' performance was impeded in the treatment that presented the semantic structures of the links. This result reflects that FI learners prefer to restructure information rather than to accept the structure provided by the materials.

Research Problem II

Will different information-conveying approaches (less explicit and more explicit approaches) and learners' cognitive styles (field dependent/field independent) affect learners' feelings of disorientation?
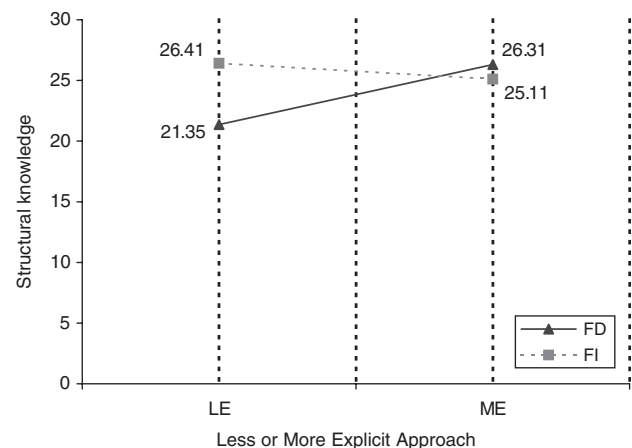

FIG. 5. Distribution lines for the mean scores of structural knowledge.

Research questions for Problem II.

- Is a subject's feelings of disorientation significantly influenced by his/her use of a less explicit approach compared with a more explicit approach?
- Is a subject's feelings of disorientation significantly influenced by his/her cognitive style (field dependent/field independent)?
- Is a subject's feelings of disorientation significantly influenced by the interaction between the approach (less/more explicit) and the subject's cognitive style (field dependent/field independent)?

From the data analysis, no significant evidence was found to support the use of the ME approach over the LE approach to reduce subjects' feelings of disorientation (.303, $\alpha > .05$). Likewise, subjects' feelings of disorientation did not differ significantly (.990, $\alpha > .05$), no matter which type of cognitive style they possessed (FD or FI).

An interaction effect was found (.018, $\alpha < .05$) (Figure 6) that signified that the interactions between the information-conveying approach and the subject's cognitive style may cause differential feelings of disorientation; this required further examination. The two information-conveying approaches were examined regarding their effects on subjects' feelings of disorientation. The results show that the FD subjects' disorientation feelings were significantly reduced by using the ME approach when compared with the FD subjects' disorientation feelings using the LE approach (.013, $\alpha < .025$). While no significant result was found, unlike the FD subjects, the FI subjects had contradictory feelings when using the ME and LE approaches. According to the mean scores of the feelings of disorientation, FI subjects did sense higher levels of disorientation when using the ME approach ($\mu = 27.50$) compared to those FI subjects who used the LE approach ($\mu = 24.59$).

Similarly, though significant difference was found, subjects' mean scores portrayed the situation as follows. FD subjects ($\mu = 29.71$) tended to feel more disorientation using the LE approach than the FI subjects did ($\mu = 24.59$). That is, with no obvious structural cues, the chances for FD subjects to get lost could increase. Meanwhile, the disorientation feelings of the FI subjects ($\mu = 27.50$) using the ME approach were relatively greater than those of the FD subjects ($\mu = 22.44$) using the ME approach. To conclude, FI subjects appeared to favor the LE approach, and complained when using the ME approach. In contrast, FD subjects depended more on the ME approach rather than on the LE approach to reduce their feelings of disorientation. In addition, FD subjects in the ME group reported the lowest feelings of disorientation among all four groups.

Research Problem III

Will different information-conveying approaches, learners' cognitive styles, learners' structural knowledge, and/or the interactions of these three correlate with learners' feelings of disorientation?
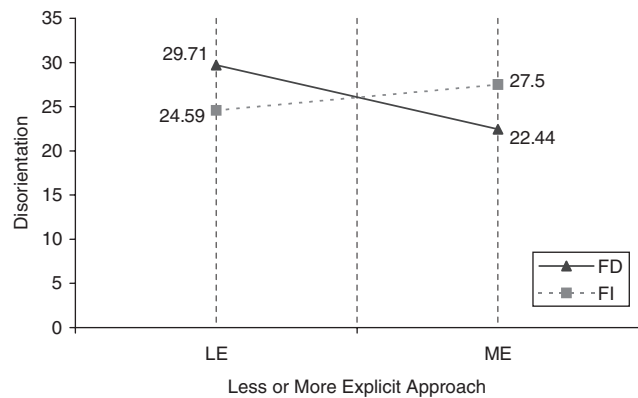

FIG. 6. Distribution lines for the mean scores of disorientation.

Research questions for Problem III.

- Is there a relationship between learners' structural knowledge and their feelings of disorientation?
- Is there a relationship between learners' structural knowledge and their feelings of disorientation in the groups using different information-conveying approaches?
- Is there a relationship between learners' structural knowledge and their feelings of disorientation for subjects with different cognitive styles?

The findings (Figure 7) for the first of these question prove Beasley (1994) and McDonald and Stevenson's (1996) assumptions that the more structural knowledge subjects gain, the fewer feelings of disorientation they will have ($r = -.540, < .01$). The second of these questions was designed to investigate in further detail how the information-conveying approach corresponds to the correlation relationship between structural knowledge and feelings of disorientation. The conclusion revealed that for subjects using the LE approach, 36.4% of the variance in their feelings of disorientation was caused by variations in their structural knowledge. This percentage is higher than the percentage (21.8%) found in examining the correlation in the ME group. For the hypothesis that examined the differences between these two population correlation coefficients, even though no significant result was found, the outcome still shows that possessing structural knowledge was more important in the LE group than in the ME group. Subjects in the LE group depended more on their structural knowledge to reduce their feelings of disorientation than subjects in the ME group did. The use of the ME approach reduced the cognitive load (from 36.4% to 21.8%) that originally relied on subjects' structural knowledge and led to the decrease in disorientation.

Similar to the second question, the third research question in this section examined how a subject's cognitive style corresponds to the correlation relationship between structural knowledge and feelings of disorientation. The data analyses indicated that 42.8% of the variance in the FD subjects' feelings of disorientation was caused by variations in their
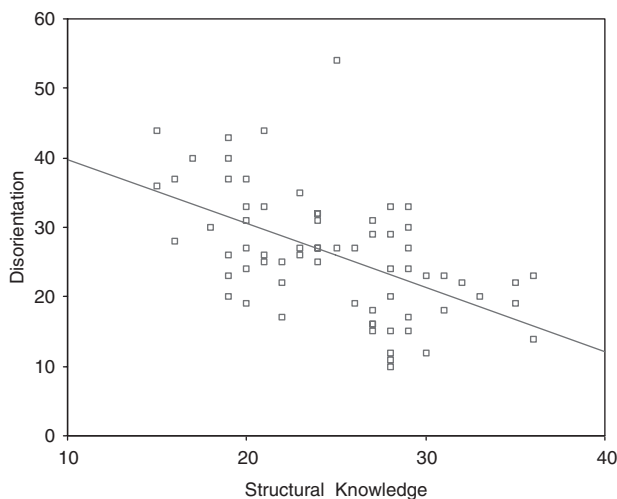
FIG. 7.   Scattergram for structural knowledge and disorientation.

structural knowledge, and 21.1% of the variance in the FI subjects' feelings of disorientation was caused by variations in their structural knowledge. Even though no statistical result was found in the follow-up investigation regarding the differences between the two population correlation coefficients (FD vs. FI), the results imply a very interesting conclusion. FI subjects seem to rely less (21.1% vs. 42.8%) than the FD subjects on their structural knowledge to help them browse the information space without worrying about getting lost. This could be attributed to the analytic learning style of the FI subjects (Ehrman, 1990). They are comfortable starting with individual concepts in a subject domain and forming the structure later, whereas the holistic learning style of the FD subjects (Riding & Cheema, 1991) makes them attempt to construct structural knowledge first so as not to feel that they might become lost.

Conclusion

A learning strategy is "the mental operations that the learner may use to acquire, retain, and retrieve different kinds of knowledge or performance" (Jonassen, Cole, & Bamford, 1992, p. 397). Learners with different cognitive styles may assimilate information in different ways, and thus will demand corresponding instructional strategies. Regarding the instructional strategy suggested by Herman and his colleagues (1987), this type of scenario should be used when learners are inclined to favor a well-organized instruction and will rely on external regulation strategies. With these particular learning patterns, this type of learner can be predicted to demand a more structured lesson, presented by means of a global approach. According to the experimental results, FD learners' structural knowledge and disorientation feelings are significantly improved by an instructional strategy that explicitly presents information in a graphical way: the concept map. The concept map, however, hampers FI learners with learning preferences for restructuring information and who depend more on their self-regulation abilities.

The experimental results of this study are consistent with Jonassen and Wang's (1993) study. The field-independent learner acquires less structural knowledge and reports higher disorientation than the field-dependent learner when both types of learners use the same concept-map instructional approach. Conversely, when the instructional strategy is less explicit (the hierarchical-associative hyperlink), the FD learners' performance dramatically declines, while the FI learners' performance increases.

The same rationale can be applied to explain the effects of minority instruction strategy (Baggett & Ehrenfeucht, 1990). While the minority (ill-structured) instructions could yield typical conceptualizations as typical (well-structured) instructions did, it could be because of the conflicts between learners' cognitive styles and received instructional strategies. The minority instructions may promote FI learners and impair FD learners, while the typical instructions may impair FI learners and promote FD learners. Baggett and Ehrenfeuch's (1990) type of ill-structured environment was preferred by the FI learner, which thus enhanced the overall performance of this group when using the minority instructions. On the other hand, it could be that FI learners' poor performance decreased the overall achievement of the group using the well-structured instructions. We may also explain Baggett and Ehrenfeuch's study in this way: The strategy of using the minority instructions was better suited than the well-structured instructions, but too many FD learners were assigned to this minority instruction group, which made the learning achievements of this group decrease. Instructional designers should consider the effects of different cognitive styles.

Careless design may damage learning results. If learners are in the introductory stage, there are two issues that hypermedia developers need to incorporate into their designs. First of all, one must help learners to construct their structural knowledge of the content domain as accurately and quickly as possible. Learners' structural knowledge profoundly affects learners' feelings of disorientation, and lack of it may frustrate learning. Also, the structural knowledge helps learners to process mental modeling smoothly, so that declarative knowledge may be correlated with procedural knowledge. The construction of structural knowledge should take priority, especially for a content novice in hypermedia learning. To achieve this learning goal, the second issue is that it is important to provide learners with an appropriate instructional strategy in accordance with their cognitive styles. Learners with a tendency to rely on external regulation strategies, such as field-dependent learners, may need well-structured and explicit instructions to learn productively. Learners with a tendency to rely on self-regulation strategies, such as field-independent learners, may favor learning by means of less-structured and more self-directed instruction.

However, once learners acquire enough experience and knowledge and start moving toward the advanced and the expert stages, different instructional strategies may need to be adopted. Learners possess different knowledge stages,

so they may well need different instructional strategies that are based on structure and that represent the hypermedia (Reed et al., 1996). There is no single learning theory (e.g., behaviorism, cognitivism, or constructivism) that can fulfill the needs of all instructional designs (Ertmer & Newby, 1993). Theory selection will need to depend on learners' categories and tasks.

Which precise types of cognitive styles and instructional strategies may influence learners' performances in the advanced and the expert stages is still open to further investigation.

Webb and Kramer (1990) raised a question regarding conceptual navigation and spatial navigation. They concluded that conceptual and spatial navigation might interfere with each other, resulting in a decrease in performance. Webb and Kramer called for further studies to investigate this topic. In accordance with the explanation of the present study's results, this proposed interference could be caused by learners' cognitive-style differences. The field-independent learner tends to employ conceptual navigation, while field-dependent learners tend to rely on spatial navigation. Learners' performance could decline if the learner is provided with a navigational aid that contradicts his/her cognitive style. Finally, the results of the present study may apply only to the situation in which the learner's knowledge level is in the introductory stage. Further investigation is needed to examine the effects of internal and external factors in the advanced and expert stages.

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Appendix
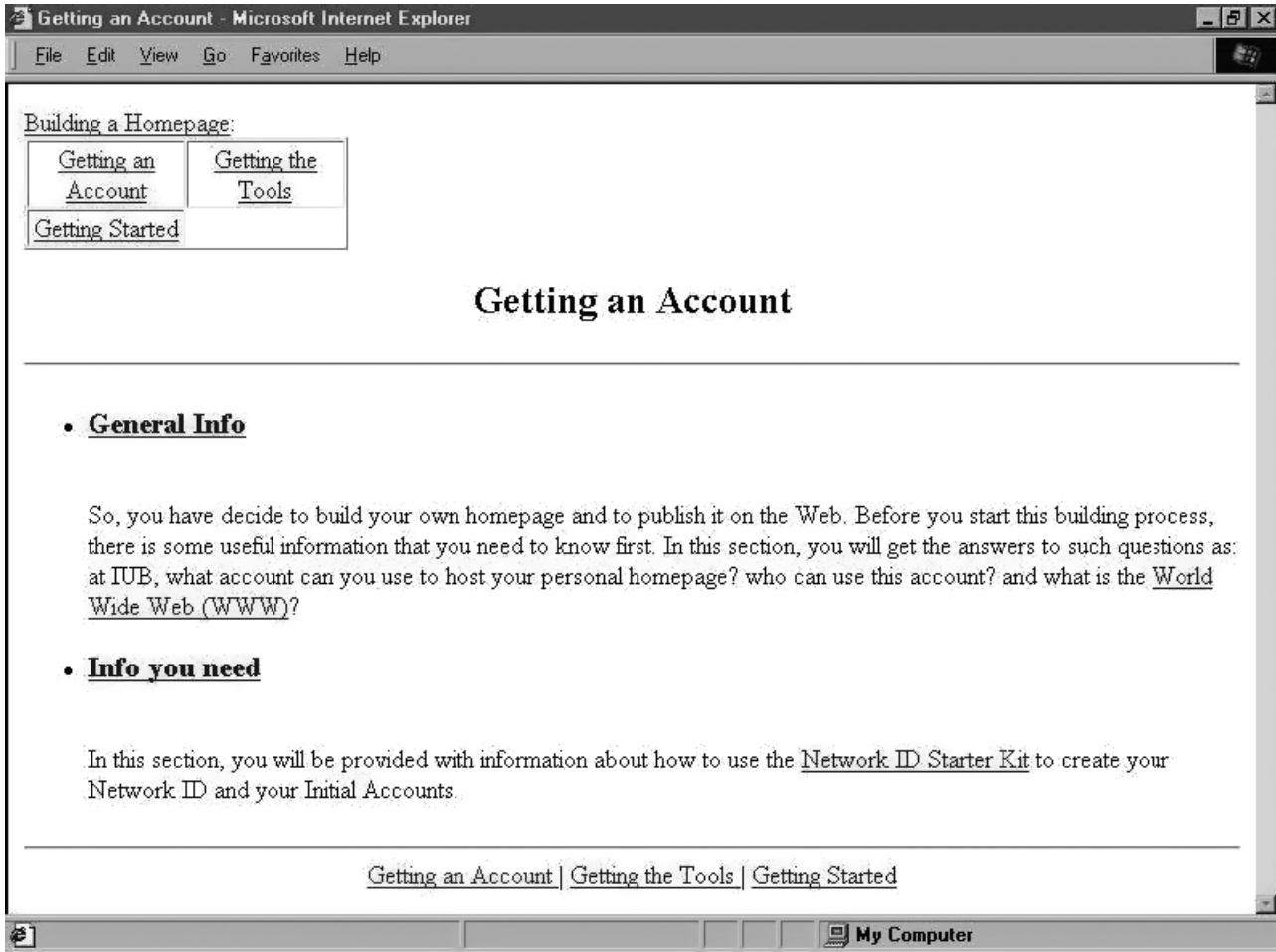
FIG. A1.   Sample page of less explicit interface.

FIG. A2.   Sample page of more explicit interface.