Technical Report No. 573

HYPERTEXT LEARNING ENVIRONMENTS, COGNITIVE FLEXIBILITY, AND THE TRANSFER OF COMPLEX KNOWLEDGE: AN EMPIRICAL INVESTIGATION

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Abstract

Although the use of hypertext systems for learning complex knowledge has been attracting recent attention, there have been few discussions in the hypertext literature on issues related to the cognitive prerequisites for learning conceptually demanding material. A study was conducted to investigate a theory-based hypertext learning environment that provided instruction in a complex and ill-structured domain. The experimental treatment incorporated several features derived from recent cognitive learning theory, in particular a hypertext procedure that presented the instructional material in multiple contexts to highlight different facets of the knowledge. The main results of the study revealed that although the control treatment led to higher performance on the measures of *memory* for factual knowledge, the more hypertext-like treatment promoted superior knowledge *transfer*. Overall, these findings suggest that hypertext learning environments that present the instructed knowledge by explicitly demonstrating critical interrelationships between abstract and case-specific knowledge components in multiple contexts would be better at preparing students to use knowledge in new ways and in new situations.

HYPERTEXT LEARNING ENVIRONMENTS, COGNITIVE FLEXIBILITY, AND THE TRANSFER OF COMPLEX KNOWLEDGE: AN EMPIRICAL INVESTIGATION

The application of hypertext systems to educational situations has been attracting considerable attention recently (e.g., Beeman et al., 1987, 1988; Conklin, 1987; Crane & Mylonas, 1988; Dede, 1987, 1988; Jonassen, 1986, 1988; Lehrer, 1991; Spiro & Jehng, 1990). Whereas some hypertext programs have been used primarily as knowledge storage and access systems, other applications of this technology have attempted to structure *learning environments* with explicit instructional goals. Many of these instructionally oriented hypertext systems have been developed in complex domains and are intended for students at an advanced stage of learning (e.g., Beeman et al., 1987, 1988; Crane & Mylonas, 1988).

Unfortunately, there have been few discussions in the hypertext literature on issues related to the cognitive prerequisites for learning conceptually demanding knowledge. Directly relevant to this concern is recent cognitive instructional research on learning complex knowledge. For example, a number of studies have documented serious conceptual misunderstandings of complex knowledge among students at different instructional levels (e.g., Feltovich, Spiro, & Coulson, 1989; McCloskey, 1983; Perkins & Simmons, 1989; Vosniadou & Brewer, 1989; White, 1983) and the frequent failure of students to appropriately transfer previously acquired knowledge (e.g., Bransford, Franks, Vye, & Sherwood, 1989; Brown, 1989; Gick & Holyoak, 1987; Lave, 1988; Schoenfeld, 1983). There has also been theoretical work that attempts to address learning problems such as these (e.g., Brown, Collins, & Duguid, 1989; Cognition & Technology Group, 1992; Glaser, 1990). In addition to addressing the issues of complexity and transfer, the recently articulated theory of learning and instruction that is central to this report, cognitive flexibility theory, has also been specifically discussed in terms of its applicability to guiding the design of hypertext learning environments (Spiro, Coulson, Feltovich, & Anderson, 1988; Spiro, Feltovich, Jacobson, & Coulson, 1992a, 1992b; Spiro & Jehng, 1990).

This report discusses a study that explored selected theoretical and design issues associated with the use of hypertext learning environments to promote the acquisition and transfer of complex and ill-structured knowledge.[1] Specifically, two approaches for structuring hypertext learning environments were used to provide instruction in a conceptually irregular domain, the social impact of technology. The experimental treatment incorporated design features derived from cognitive flexibility theory, in particular a procedure that provided several presentations of the instructional material in multiple contexts to highlight different facets of the knowledge. This approach was postulated to develop flexible cognitive structures that would enhance the ability of learners to transfer their previously acquired knowledge to new application situations. The control treatment used a minimal hypertext/computer-based drill that consisted of several design features that were antithetical to those of the experimental condition. The control condition was intended to present the same instructional content in a more rigid and decontextualized manner and was hypothesized to foster greater mastery of factual knowledge, but with a lesser level of achievement on tests of knowledge transfer. The possible influence of fundamental epistemic beliefs held by the students concerning the nature of knowledge and learning on their ability to learn using a hypertext environment was also investigated.

[1]Ill-structured knowledge domains are comprised of many concepts that are relevant in a typical knowledge application situation and where the application of a concept or combination of concepts can vary widely across different case situations (Spiro et al., 1988; for a discussion, see Jacobson & Spiro, 1991).

Theoretical and Research Perspectives

Cognitive Flexibility Theory

This recent cognitive theory of case-based learning has been specifically articulated to address problems associated with the acquisition and transfer of complex knowledge (Spiro et al., 1988). A central theme of cognitive flexibility theory (CFT) is that the *oversimplification of complex knowledge* is a significant contributing factor to many examples of learning failure (e.g., Coulson, Feltovich, & Spiro, 1989; Feltovich et al., 1989; Myers, Feltovich, Coulson, Adami, & Spiro, 1990; Spiro et al., 1988; Spiro, Vispoel, Schmitz, Samarapungavan, & Boerger, 1987). CFT proposes a number of instructional principles that are intended to avoid inappropriate oversimplifications of complex knowledge at an advanced instructional level, but in a manner that makes understanding this material cognitively tractable. In particular, there are five CFT instructional principles that are relevant for the present study (see Spiro et al., 1988, for a more detailed discussion):

1. **Multiple knowledge representations.** The use of a monolithic or unidimensional depiction of complex and ill-structured knowledge frequently misrepresents important conceptual facets of the domain (Spiro et al., 1987; Spiro et al., 1988). CFT recommends employing multiple ways to represent knowledge in instructional activities (e.g., multiple themes, multiple analogies, multiple intellectual points of view) to reflect more accurately the multifaceted nature of complex knowledge.

2. **Link and tailor abstract concepts to different case examples.** In ill-structured content areas, there is considerable variability in terms of how abstract concepts apply to actual case situations. CFT recommends illustrating abstract concepts using multiple case examples to demonstrate to the learner the nuances of abstract conceptual variability associated with ill-structured domains to the learner (Spiro et al., 1988, Spiro & Jehng, 1990).

3. **Early introduction of domain complexity.** A common instructional approach is to break a complex topic into small conceptual units, learn these units in isolation, and then to combine the units. Unfortunately, this approach tends to oversimplify and decontextualize complex material (e.g., Brown, 1989; Spiro et al., 1988). As an alternative, CFT recommends the early introduction of complexity in a cognitively manageable manner that still reflects some of the multifaceted interactions of various conceptual elements (Spiro & Jehng, 1990). The advanced learner is thus prepared for a deeper explication of the knowledge with further study that is not *qualitatively* different from the earlier instruction.

4. **Stress the interrelated and web-like nature of knowledge.** CFT proposes that the demonstration of conceptual interrelationships in multiple contexts helps cultivate a rich and flexible understanding of a complex content area. In contrast, teaching isolated and abstracted knowledge elements may produce more rigid or "inert" knowledge representations that limit the ability of the learner to apply the knowledge in new knowledge application situations (Bereiter & Scardamalia, 1985; Bransford et al., 1989; Spiro et al., 1987).

5. **Encourage knowledge assembly.** In a complex and ill-structured domain, frequently there is germane knowledge from a variety of previously learned conceptual and case sources that is relevant to a novel knowledge application situation. Rather than requiring the learner to retrieve from memory a single, precompiled monolithic knowledge schema that may not be appropriate to a new situation, CFT proposes that the learner *assemble* relevant abstract conceptual and case-specific knowledge components for a given knowledge application or problem-solving task.

In addition to these general instructional recommendations, CFT may be used to provide a theoretical framework to guide the development of hypertext learning environments (Spiro et al., 1988; Spiro et al., 1992a, 1992b; Spiro & Jehng, 1990). Several prototype proof-of-concept hypertext and hypermedia systems that implement CFT design recommendations have been developed. As will be detailed below, the experimental and control treatments of this study varied in their utilization of these five CFT principles for research purposes.

Epistemic Beliefs about the Organization of Knowledge and the Nature of Learning

Another relatively recent area of cognitive inquiry of potential relevance to hypertext and hypermedia investigators and developers involves research into the influence on learning associated with *epistemic cognition*, specifically student beliefs about the structure of knowledge and the nature of learning. In contrast to metacognition, which refers to cognitive monitoring and self-regulatory processes, epistemic cognition is concerned with the nature and influence of presumably nondomain specific general belief systems related to the acquisition and structure of knowledge (e.g., Kitchener, 1986; Schommer, 1990). Schoenfeld (1983) proposed that an individual's fundamental belief systems may operate at a "control" level that shapes a person's behavior in solving problems. These *epistemic beliefs*,[2] which may not be consciously held, could determine the kind of cognitive resources the student accesses in performing learning and problem-solving tasks, even rendering inaccessible large amounts of information available in long-term memory that could be easily retrieved under different circumstances. A student's epistemic beliefs have been associated with such learning problems as the failure to integrate new knowledge with prior knowledge, use of rigid criteria for monitoring reading comprehension, and poor performance on comprehension measures (Schommer, 1990). There have also been suggestions that epistemic beliefs favoring the oversimplification of complex and ill-structured knowledge contribute to the formation of conceptual misunderstandings at post-introductory stages of learning (Feltovich et al., 1989; Spiro et al., 1988). To date, no studies have been reported that explore epistemic cognition within the context of using a hypertext learning environment. This issue may be particularly important in trying to ascertain the effectiveness of innovative computer learning environments that may have characteristics (e.g., nonlinear access to interrelated knowledge components, emphasis on knowledge transfer and independent thinking instead of rote memorization of prespecified facts) that conflict with particular epistemic beliefs held by the student.

Overview of Study and Experimental Hypotheses

The hypertext materials used in the study consisted of two main parts. In part one, the "reading stage," both groups read the same instructional content in a hypertext format based on the first three CFT design features discussed above (use multiple knowledge representations, link abstract concepts to case examples, and early introduction of complexity). In part two, the "study stage," the experimental group received a hypertext treatment, Thematic Criss-Crossing Hypertext, that also implemented the fourth and fifth CFT design principles (stress knowledge interrelationships and emphasize knowledge assembly). At the same stage, the Minimal Hypertext/Drill control group completed a computer-based drill over facts and thematic concepts taken from the "reading stage" that was intended to provide a highly contrasting instructional activity compared to the Thematic Criss-Crossing Hypertext activity.

It was hypothesized that the Minimal Hypertext/Drill control group, which received structured practice over prespecified material, would achieve higher scores on the predominantly memory tests of factual knowledge than the experimental group. However, the more rigidly structured knowledge of the control group was anticipated to be less accessible to flexible, situation-specific manipulation for novel

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[2]In this report, the term *epistemic* is used rather than *epistemology*. While epistemology is concerned with the study of the nature of knowledge and its limits and validity, epistemic refers to the more general character of knowledge or knowing as a type of experience. Thus, we prefer the term epistemic for the broader connotative sense it conveys.

knowledge application situations, resulting in lower scores on the transfer test than for the experimental Thematic Criss-Crossing Hypertext group.

In terms of the influence of epistemic beliefs on the subjects' ability to learn using the experimental materials, it was expected that some learners would prefer instructional approaches that tend toward context simplification (rather than complexity) and that stress the memorization of prespecified knowledge (Spiro et al., 1987). Learners holding such beliefs, which we refer to as *simple epistemic beliefs and preferences* (*simple EBP*), were expected to be less able to learn with the nonlinear and multidimensional computer environment that was used in the experimental hypertext treatment. In contrast, we anticipated that learners with more *complex epistemic beliefs and preferences* (*complex EBP*)--who welcomed working with complex knowledge in multiple ways and who valued more active learner construction of knowledge--would be more successful at learning with the experimental hypertext treatment.

Method

Subjects

Subjects were freshman and sophomore university students who were paid for their participation in the study. They were randomly assigned to one of three experimental treatment groups (22 to Thematic Criss-Crossing Hypertext and 11 each to Minimal Hypertext/Drill I and Minimal Hypertext/Drill II). Of the 39 subjects who completed the study, three had missing data and were eliminated from the pool. To obtain an equal number of subjects in the experimental treatment groups, two additional subjects were selected at random and dropped from the final statistical analysis. In the final pool of 34 subjects (17 in each group), 25 (73.5%) were female and 9 (26.5%) were male.

Content

The topic for the instructional treatments, the impact of technology on twentieth-century society and culture, is a complex domain that may also be characterized as being conceptually ill-structured due to its multidisciplinary nature and the highly diverse and dynamically changing real world situations to which this knowledge must be applied. This instructional domain is also one with which university-level students were assumed to have some familiarity because of previous exposure to formal course work in the social and natural sciences, common information sources (such as newspapers, magazines, and television), and personal experience from living in our technology-rich, late-twentieth-century culture. However, the social impact of technology is not a standard undergraduate academic major for students to specialize in, thus minimizing a possible confounding factor resulting from certain subjects possessing an extensive degree of prior knowledge in this area. Instructionally, it was anticipated that the subjects would be able to learn some of the advanced intellectual dimensions of this field found in the scholarly literature in the period of time available for the study (about five hours of instructional time on the computer). Finally, this topic was hoped to be of some general interest to the subjects and thus to motivate more compliant subject behavior during the administration of the study. The content for the hypertext program used in this study, *Technology and the Twentieth Century: Impact on Society and Culture*, was prepared by the first author after conducting readings in the professional literature (e.g., Berman, 1988; Bernstein, 1987; Bijker, Hughes, & Pinch, 1987; Borchert & Stewart, 1979; Callon, 1987; Camenisch, 1987; DeVries, 1987; Ellul, 1954/1964; Goldberg & Strain, 1987; Howard, 1985a, 1985b; Murphy, Mickunas, & Pilotta, 1986; Siegel & Markoff, 1985).

Cognitive Flexibility Hypertext Design Features Common to Both Experimental and Control Conditions

Three CFT design principles were implemented in the hypertext materials used by both groups during the reading stage (see Table 1). This section describes these theory-based elements and shows selected screens from the reading stage portion of the hypertext program used by both groups.

[Insert Table 1 about here.]

Multiple representations of knowledge. The use of multiple representations of knowledge in instruction is a central recommendation of CFT that is intended to help avoid the oversimplification of difficult material. The hypertext materials that were presented to both groups during the reading stage attempted to represent some of the complexity associated with the social impact of technology domain through the use of six case examples and six abstract conceptual or thematic dimensions of analysis applied to each example. The six cases described different examples of technology and society in such diverse areas as medicine, automotive transportation, and computers (see Table 2). These cases were analyzed from the perspective of six different broad scope and partially overlapping thematic dimensions of analysis: *Socially Constructed Nature of Technology*; *Actor Networks*; *Progress - Problems*; *Freedom - Control*; *Technological Efficiency*; and *Community - Alienation*.

[Insert Table 2 about here.]

Tailor abstract concepts to case examples. In an ill-structured domain, there is substantial variability in the application of abstract concepts to specific case situations. To help illustrate this conceptual variability, the six cases were subdivided into smaller units referred to as *minicases*. Each minicase consisted of a short section of text describing a portion of the case, a list of the relevant themes, and thematic commentaries that described how the conceptual themes are *tailored* to the particular case. The minicases were analyzed from the perspective of the six social impact of technology themes and applicable themes were placed in a Theme List (see Table 3 for a matrix of three cases, their minicase text sections, and the associated theme vectors). For example, in the first minicase of the "Aborted Introduction of the French Electric Car," the applicable themes were the *Socially Constructed Nature of Technology* and *Actor Networks*, while in the second minicase section, "The EDF Plan" (see Figure 1), five themes were analyzed as being relevant. In addition, thematic commentaries were written that briefly explained the relationship of the abstract themes to the specific minicase texts (see Figure 2).

[Insert Table 3 about here.]

Early introduction of complexity. The minicase sections were intended to present some aspects of the conceptual complexity and ill-structuredness associated with the social impact of technology domain, but in a manner made more cognitively tractable by the fact that the multiple themes could be understood against a smaller, more manageable amount of background information. Much could be learned from the study of even a single minicase. For example, "The EDF Plan" (the second minicase text section of the case "The Aborted Introduction of the French Electric Car") described how in the 1970s the engineers at the *Electricité de France* utility attempted to develop an electric car. They were not only concerned with technological factors of the project, but also with the numerous social ramifications that would result from the implementation of such a new technology (see Figure 1). This case-specific information was analyzed in terms of more abstract conceptual dimensions, the social impact of technology themes. As "The EDF Plan" minicase is fairly rich in content, five of the six social impact of technology themes were identified as being relevant and were listed in the Theme List (see Figure 2). The commentaries for these themes, such as *Community - Alienation* (also shown in Figure 2), each elaborated on the minicase-specific material in different ways. In a similar manner as "The EDF Plan," each minicase--with its text, themes, and theme commentaries--provided a relatively self-contained unit of instruction that was short, yet revealed significant aspects of the conceptual complexity associated with this subject matter. Further elements of domain complexity were then introduced as the learner read each of the minicase text sections for an entire case in conjunction with the attendant themes and commentaries. Over the course of the study, this instructional cycle was repeated as additional contrasting cases were introduced.

[Insert Figures 1 and 2 about here.]

Main Features of the Experimental Condition

As noted earlier, the experimental group used a Thematic Criss-Crossing Hypertext procedure during the study stage that incorporated two additional CFT design principles: *interrelated nature of knowledge* and *knowledge assembly* (see Table 1). The hypertext implementation of these two CFT design principles are discussed in turn.

Stress interrelated and web-like nature of knowledge. The Thematic Criss-Crossing Hypertext allowed a theme-based exploration of the minicase text sections in which the initial linear sequencing of material used in the reading stage was re-edited by the program to permit the *nonlinear* linking of minicases based on different theme combinations. This rearrangement of the hypertext link/node relationships between the minicase text sections was intended to demonstrate different conceptual and case interrelationships that may have been unnoticed by the subject during the reading stage. Over the course of the entire study, subjects in the Thematic Criss-Crossing Hypertext treatment reread minicase text sections and the applicable theme commentaries for 15 different theme combinations. As an illustration, the theme combinations of *Progress - Problems* and *Community - Alienation* were applicable to 10 minicases in 4 cases (see Table 3 for some of the minicases matching these two themes; Figure 3 shows one minicase from the UTOPIA Project with these two themes listed in the Theme List), while the theme combinations of *Freedom - Control* and *Technological Efficiency* were relevant to 14 minicases drawn from all 6 cases. Overall, the "criss-crossings" of the minicases from the contrasting intellectual perspectives represented by the theme combinations were intended to demonstrate abstract conceptual *interconnections* across different case examples and thus to highlight different facets of the domain knowledge. The theme combinations for this study were preselected to insure that all subjects had read the same material and covered an appropriately diverse mix of themes and minicases. (Future research is planned that would investigate learning outcomes associated with learner selection of theme combinations.)

[Insert Figure 3 about here.]

Encourage the assembly of knowledge from different conceptual and case sources. CFT suggests that over reliance on rote memory is a problematic cognitive learning strategy in a complex and ill-structured domain because acquired knowledge frequently must be applied in ways that differ from the initial knowledge encoding situation. For this reason, the Thematic Criss-Crossing Hypertext procedure made no explicit attempt to foster memorization of specific abstract or case-specific knowledge. Instead, the Thematic Criss-Crossing Hypertext procedure presented different ensembles of relevant case-specific texts based on various abstract conceptual criteria. It was hypothesized that the experimental subjects receiving this interconnected exposure to the instructional materials would be better able to assemble their acquired knowledge for application on the transfer tasks than the control subjects receiving the more rote memory oriented control drill treatment.

Main Features of the Control Condition

Reading stage. Two control conditions (referred to as Minimal Hypertext/Drill I and Minimal Hypertext/Drill II) were developed that presented slightly different materials during the reading stage but used the same computer-based drill design for the study stage. Previous studies investigating CFT attempted to induce a flexible or rigid cognitive representation of the domain knowledge partially through directions to the subjects during the knowledge-acquisition period to concentrate on either multiple themes or a single theme, depending on the treatment condition (Hartman & Spiro, 1989; Spiro et al., 1987). A similar procedure was adapted for use in this study, with the experimental group instructed to concentrate on multiple themes applicable to the cases and the control group instructed to concentrate on a single important theme for each case.

However, there were concerns that encoding differences during the reading stage between the experimental and the control conditions could confound the primary research interest, which was the influence of the Thematic Criss-Crossing Hypertext procedure compared to the computer-based drill in the study stage. Consequently two slightly different control conditions were created: Minimal Hypertext/Drill I and Minimal Hypertext/Drill II. In the Minimal Hypertext/Drill I condition, the subjects were given instructions that each of the six cases best exemplified one of the six themes and a couple of sentences of text were added to each case to highlight the relevant theme. The Minimal Hypertext/Drill I subjects were then given further directions that although the other themes may have some degree of applicability, they were to concentrate on the single most important theme identified for each case. In the Minimal Hypertext/Drill II control condition, the same reading stage instructions and content were administered as with the experimental Thematic Criss-Crossing Hypertext condition. See Table 4 for a summary of the differences between the three treatment conditions.

[Insert Table 4 about here.]

Study stage. The computer-based drill administered to the control group during the study stage possessed a number of features that were intended to be antithetical to those used for the Thematic Criss-Crossing Hypertext treatment in the experimental group. The design for the control treatment was based on an approach developed by Siegel and Misselt (1984) that incorporated a number of features that have been recommended for computer-based drills, such as: promote automaticity through practice, create conceptual interference using the review of old items as new ones are introduced, and use spaced practice and review (Salisbury, 1990). The drill program for the control treatment presented a series of multiple-choice questions based on factual and thematic content from the reading stage and provided feedback in terms of the correctness of the subject's response. All items were required to be answered correctly at least two times before being removed from the item queue. Missed items received additional practice by having another drill question inserted before reviewing the missed item, then inserting two different drill questions before the missed item, and finally inserting three different drill questions before the missed item.

There were several ways in which this computer-based drill design approach was intended to contrast with the CFT design principles used in the Thematic Criss-Crossing Hypertext treatment. For example, studying the Technology and Society content area through the use of multiple-choice questions inherently *simplified and abstracted* the material compared to the case-based Thematic Criss-Crossing Hypertext procedure. Also, the mastery approach reflected in the drill program (e.g., answer each question correctly at least two times, provide additional spaced exposure to missed items) tended to emphasize rote *memorization*, in marked contrast to the CFT principle to stress *knowledge assembly* from different conceptual and case sources.

Additional Treatment Features

There are additional features of the experimental and control treatments that deserve brief mention. In the reading stage, general descriptions of the social impact of technology themes were available by selecting Help. The subjects were required to read the general theme descriptions during Sessions 1 and 2 of the study, and these theme descriptions were also optionally available as the subjects read the hypertext materials during all sessions. In addition, the subjects in both conditions were required to read all of the thematic commentaries in all of the minicase text sections during the reading stage. The program would alert the subject if a theme commentary had been skipped and would place the subject at the first occurrence of a missed theme commentary.

During the study stage, an intrinsic feature of the control treatment was its interactivity, as the computer-based drill provided specific feedback to the subject in terms of the correctness of his or her responses. In contrast, the experimental Thematic Criss-Crossing Hypertext treatment involved less overt interactivity as it primarily consisted of a reading-oriented activity. To compensate for the different degree of interactivity associated with the control and experimental treatments, a short Theme Identification module was developed for the experimental treatment. This involved presenting minicase text sections that had been previously read, and required the subject to select the social impact of technology themes she or he thought were applicable (the original Theme List was hidden during this activity). After the themes were selected, the program compared the subject's theme list with the original theme list, provided a short message about the accuracy of the subject's list, and displayed the original theme list for the subject to study if desired.

The Minimal Hypertext/Drill I and II groups also received practice identifying themes, but within the context of the computer-based drill. For example, a minicase text section would be presented with five different combinations of themes listed for the subject to select from. In keeping with the overall format of the drill, a missed theme identification question was placed in the queue of missed items so that the subject would see that question for additional practice. Although the theme identification questions for both groups required a higher order analysis of the minicase text sections (i.e., not just use of rote memory) to determine the appropriate themes, the drill treatment still tended to implicitly emphasize the memorization of a particular answer for theme identification items. This occurred because a missed theme identification question was placed in the incorrect item queue, so that the subject saw the same question several times (the program did insert spacing items and scrambled the order of the multiple-choice answer and the distracter options to help minimize surface position cues that might reveal the answer). Overall, the drill treatment on theme identification was designed to present similar instructional content as the experimental treatment involving theme identification, but in a manner intended to foster more rigid cognitive representations of the material through an instructional procedure that emphasized rote memory.

Test Materials

A vocabulary test (French, Ekstrom, & Price, 1963) was given to provide an easily administered, general measure of verbal ability (Anderson & Freebody, 1979). An EBP instrument was also administered to provide a measure of the types of beliefs held by the subjects concerning the nature of learning and the organization of knowledge. This instrument was initially developed by the second author, Paul Feltovich, and Richard Coulson for an epistemic cognition study involving medical school students. The version of the EBP instrument used in this study consisted of 19 pairs of related statements, with one statement positively worded and the second statement negatively worded. Subjects rated the degree to which they agreed or disagreed with each item on a 7-point Likert scale.[3] Four representative items from the EBP instrument are listed in Table 5.

[Insert Table 5 about here.]

The main dependent measures were short-answer questions on the Technology and Society content and two problem-solving essays written after reading new problem scenarios related to technology and society. (Because of space limitations, less pertinent secondary data that were collected in the study are not discussed in this paper; see Jacobson, 1990.) The scenario for the first problem-solving essay administered after Session 2 placed the subject in the role of an educational technology consultant to the school board of a large urban school district who had to write a short report on the impact of educational technologies on the school district. For the Session 4 test, the scenario described a hypothetical United Nations task force investigating alternative world energy sources, environmental problems, and economic disruptions after the year 2000. The subject was given the role of the project director who had to write an overview of the task force's report. For each essay, the subjects were given 15 minutes to write their analysis of key issues and their proposed solutions to problems posed in the scenario. As these essays were intended to be transfer measures, they were on topics *unrelated* to the cases presented during the learning phase of the study.

Experimental Procedure

The study was administered on four separate days, Sessions 1-4, for approximately two hours on each day. Sessions were held on either Monday and Wednesday or Tuesday and Thursday for two consecutive weeks. At Session 1, a pretest was given and basic instruction was provided on the use of the Macintosh computer hardware and the hypercard programmed experimental software. The subjects studied the instructional content in the hypertext program on each of the four sessions of the study during the reading stage and study stage activities, reading one case at Session 1, two cases each during Sessions 2 and 3, and the last case during Session 4. The main evaluation instruments were completed at the end of Sessions 2 and 4.

Results

This section summarizes the major statistical results of the study. The first research hypothesis dealt with the possible differences in the performance on the short-answer questions and the problem-solving essays between subjects in the two Minimal Hypertext/Drill treatment conditions (n(Minimal Hypertext/Drill I) = 8; n(Minimal Hypertext/Drill II) = 9). A multivariate analysis of variance (MANOVA) was run that compared the Minimal Hypertext/Drill I and Minimal Hypertext/Drill II groups on the short-answer and problem-solving essay questions; no significant difference between the two Minimal Hypertext/Drill groups was found (Wilks' lambda = 0.89), $F(4,12) = 0.37, p = .83$. For all subsequent analysis, the Minimal Hypertext/Drill I and Minimal Hypertext/Drill II groups were collapsed into a single Minimal Hypertext/Drill group, resulting in two treatment groups (Thematic Criss-Crossing Hypertext and Minimal Hypertext/Drill) comprised of 17 subjects each.

Analysis of variance revealed no significant difference between the two groups on short-answer factual questions answered after reading a short technology and society case administered during the *pretest*, $F(1,32) = 0.34, p = .56$. However, the Minimal Hypertext/Drill group achieved significantly higher mean scores on the short-answer questions of factual knowledge for both the Session 2 and Session 4 tests (see Table 6 for means; between subjects effects: $F(1,32) = 2.79, p = .05$. As the main

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[3]In the administration of this instrument, the negatively worded form of one item was inadvertently presented twice, thus leaving a total of 37 items for statistical analysis.

experimental hypotheses were directional in nature, one-tailed levels of significance are reported.) The Minimal Hypertext/Drill subjects completed their study stage sessions in a significantly shorter period of time (calculated by summing the number of minutes spent in the study stage for each of the four sessions; Minimal Hypertext/Drill: M = 82.62 minutes, SD = 15.09; Thematic Criss-Crossing Hypertext: M = 125.04 minutes, SD = 25.00; between groups: $F(1,32) = 37.39, p < .01$). Using the total study stage duration in conjunction with the estimate of verbal ability (vocabulary score) as covariates, a between- and within-subjects repeated measures ANCOVA was then run that confirmed the Minimal Hypertext/Drill group achieved significantly higher scores on the short-answer tests over the Thematic Criss-Crossing Hypertext group (between subjects effects: $F(1,30) = 14.54, p < .01$). Together, these findings indicate that the Minimal Hypertext/Drill treatment was more effective and efficient than the Thematic Criss-Crossing Hypertext treatment at promoting the acquisition of factual knowledge.

[Insert Table 6 about here.]

Higher order conceptual transfer was assessed through the problem-solving essays that were scored by the first author and two other trained raters who were all blind to the subjects' treatment assignments. The raters were instructed to assign letter grades to the essays ranging from E- to A+ (i.e., a 15 point scale) based on a holistic rating of the responses. In determining the holistic score, the raters considered the analysis of key issues of the problem, quality of the resolution for the scenario conflict, overall originality of ideas (especially new ideas, not just copying ideas already contained in the scenario passage), writing quality, and persuasiveness of the essay. All essays were scored individually by the raters and scoring discrepancies were resolved through discussion. In a follow-up reliability analysis, two additional trained raters scored a randomly selected group of the problem-solving essays (27 and 38, respectively) (Garner, Alexander, Gillingham, Kulikowich, & Brown, 1991). The essay scores were then collapsed to a 5-point scale reflecting E to A grades and a percentage agreement interrater reliability procedure was employed (Baker & Niemi, 1991). The percentage agreement plus or minus one point between the initial group consensus scores of the essays and the scores of the two follow-up raters was 81.8% and 81.6%, respectively. Statistical analysis of the problem-solving essay scores was based on the initial three rater group consensus scores. In contrast to the short-answer scores, the mean scores on the problem-solving essay tasks were consistently higher for the Thematic Criss-Crossing Hypertext group (Table 6 and Figure 4). Although the Session 2 scores were not significantly different between the two groups, $F(1,32) = 0.48, p = 0.25$, by Session 4 the Thematic Criss-Crossing Hypertext group had achieved significantly higher problem-solving essay scores than the Minimal Hypertext/Drill group, $F(1,32) = 7.03, p < .01$.

[Insert Figure 4 about here.]

As noted above, the Minimal Hypertext/Drill group completed their study stage treatment in significantly less time than the Thematic Criss-Crossing Hypertext group. Using the study stage duration and vocabulary scores as covariates in a SPFAC 2•2 design (Kirk, 1982) revealed a significant group-by-session interaction (within-subjects interaction: $F(1,30) = 2.82, p = .05$). This last analysis (which is consistent with the significant difference found on the ANOVA of the Session 4 essay scores reported earlier) indicates that when the problem-solving essay scores are adjusted for differences in verbal ability and the longer study stage duration of the Thematic Criss-Crossing Hypertext, there is still a significant difference between the Thematic Criss-Crossing Hypertext and the Minimal Hypertext/Drill groups on the essays by the last session of the study. That is, the Thematic Criss-Crossing Hypertext essay performance is significantly greater by Session 4 even when the extra study time is statistically used against it.

Epistemic Beliefs and Preferences

Three subjects failed to complete all items on the EBP instrument and thus were excluded from the analyses conducted in this section. The negatively worded items were recoded positively (i.e., 1 = 7, 2 = 6, etc.), and a score for each subject was calculated by totaling the Likert scale selections for each item, yielding a possible range of 37 to 259 for the EBP instrument (larger numbers indicated more complex EBP). This instrument was found to have a moderately high internal reliability (Cronbach's alpha = 0.75), and there was no significant correlation between the EBP and vocabulary test scores ($r = 0.14, p > .05$). Subjects with a score above the mean ($M = 155$, $SD = 17$) were assigned to a "complex EBP" group and subjects below the mean were assigned to a "simple EBP" group. A significant interaction was found for the experimental treatment group x EBP group on the problem-solving essays (between-subjects effect: $F(1,27) = 5.50, p < .01$) (see Table 7 and Figure 5). As there was no significant within-group "session" effect, the Session 2 and Session 4 problem-solving essay scores were collapsed to a single overall problem-solving essay score. Simple main effects were then tested, using Dunn's procedure to set the significance level at .035 as the error rates for simple main effects tests are not mutually orthogonal (Kirk, 1982). Two significant simple main effects were found: (a) treatment group at the complex EBP level, $F(1,27) = 7.89, p < .01$; and (b) EBP group using the Thematic Criss-Crossing Hypertext, $F(1,27) = 4.42, p = .02$. These findings indicated that the significant interaction was due to: (a) higher essay scores for the complex EBP subjects in the Thematic Criss-Crossing Hypertext group as compared to the lower essay scores for the complex EBP subjects in the Minimal Hypertext/Drill group; and (b) higher essay scores of the complex EBP subjects compared to the simple EBP subjects after receiving the experimental Thematic Criss-Crossing Hypertext treatment.

[Insert Table 7 about here.]

[Insert Figure 5 about here.]

Discussion

Computer-Based Drills and the Inculcation of Inert Knowledge

The finding that the Minimal Hypertext/Drill group had higher scores on the factual knowledge items was in the predicted direction. Given the greater amount of factual knowledge possessed by the Minimal Hypertext/Drill subjects, the question may be asked: Why could not the Minimal Hypertext/Drill group *use* this knowledge as well as the Thematic Criss-Crossing Hypertext group on the problem-solving transfer tasks?

There are two related cognitive interpretations for the lack of knowledge transfer in the Minimal Hypertext/Drill group: *rigid knowledge representations* (Spiro et al., 1987) and *inert knowledge* (e.g., Bereiter & Scardamalia, 1985; Bransford et al., 1989). Spiro and associates (1987) proposed that simplifying instructional strategies can produce rigid and monolithic representations of knowledge that inhibit the ability of learners to use their knowledge in new contexts. Such rigid types of knowledge structures are hypothesized to consist of a limited number of access routes to the previously acquired knowledge. This would require the learner to retrieve and apply the knowledge under conditions that were highly similar to those that existed during the initial instruction. A similar view has been articulated by Bereiter and Scardamalia (1985) and Bransford et al. (1989), who adopt Whitehead's (1929) notion of "inert knowledge." As the "periodic table" analogy suggests, inert knowledge does not interact or combine with other knowledge the student possesses. Two distinguishing characteristics of inert knowledge are: (a) the accurate ability of students to reproduce knowledge under one set of conditions (i.e., those matching the encoding context), and (b) the inability of students to apply this knowledge in new knowledge application contexts (i.e., a transfer situation).

From these two similar perspectives, the Minimal Hypertext/Drill group had developed rigid or inert knowledge structures for their social impact of technology knowledge. The knowledge acquired by the Minimal Hypertext/Drill group was bound to certain contexts associated with the encoding process (i.e., the simplified and abstracted multiple-choice format in which the knowledge was practiced in the drill). The short-answer questions covered primarily factual information in a manner similar to the multiple-choice format of the drill items (indeed, a number of the questions covered the same material). Given the similarity of the knowledge application situation associated with the short-answer questions to the multiple-choice items used in the study stage, it is not surprising that the Minimal Hypertext/Drill group performed at a significantly higher level on the factual knowledge tests than the Thematic Criss-Crossing Hypertext group. However, when the Minimal Hypertext/Drill subjects were required to *use* their knowledge in a context that contrasted sharply from the original knowledge-acquisition context, the problem-solving essay, they performed at a significantly lower level than the Thematic Criss-Crossing Hypertext group. As predicted, the Minimal Hypertext/Drill subjects were less able to access their acquired knowledge and to link it in a situation appropriate manner to the new knowledge-application tasks.

Thematic Criss-Crossing Hypertext: Promoting the Transfer of Knowledge

The significant transfer effects found by Session 4 with the Thematic Criss-Crossing Hypertext treatment were consistent with the theoretical framework of the study. The first CFT instructional principle used in the this treatment, *demonstrate the interrelated and web-like nature of knowledge*, presented the minicase text sections from various intellectual perspectives associated with the different theme combinations. This allowed various case-specific elements of knowledge to be explicitly linked and interconnected to each other and to the abstract technology and society themes.

The second instructional principle attempted to promote *knowledge assembly* and to de-emphasize rote memorization. It may also be that part of the effectiveness of the Thematic Criss-Crossing Hypertext treatment was due to the actual *modeling of knowledge assembly* through the computer re-editings of the link relationships between the minicases based on different theme combinations. The Thematic Criss-Crossing Hypertext procedure essentially demonstrated a way in which different hypertext knowledge components (i.e., the minicases and themes) could be combined and recombined in different ways. It could be that exposure over time to this hypertext-based modeling of knowledge assembly helped the subjects to internalize and improve their own ability to cognitively assemble knowledge from diverse conceptual and case sources.

Although a significant difference between the two groups on the transfer measure did not appear until the Session 4 problem-solving essay task, this delayed manifestation of the instructional effectiveness of the Thematic Criss-Crossing Hypertext was expected for two reasons. First, the Thematic Criss-Crossing Hypertext treatment represented a completely new type of instructional activity for the subjects and they may have needed a couple of sessions to become familiar with it. Second, and more importantly, we had anticipated that the subjects would require a period of time in order to assimilate the wide range of thematic and case associations that were presented during their instructional treatment. Given the positive findings of transfer even over the limited two week period of the present study, we are planning future research into the longer term use of hypertext learning environments of this type and their application in real classroom situations.

Implications for the Design and Use of Hypertext Learning Environments

A central concern of this study was the investigation of theory-based design principles for a hypertext learning environment to provide instruction in a complex and ill-structured content area. There are several important implications of this research project for the design and use of hypertext systems in instructional settings. This section discusses some of the specific design features of the CFT hypertext treatment, and concludes with a general consideration of the instructional applications of technology-based learning environments of this type.

Multiple virtual links to case-based hypertext nodes. There are several hypertext design features used for the Thematic Criss-Crossing Hypertext treatment that vary from other instructional hypertext systems described in the literature. During the reading stage, the hypertext links to the minicases were essentially *linear* in nature, being determined by the narrative flow of the text sections associated with each case. Hierarchical access to the abstract, theme list, and theme commentary nodes was then available from each of the minicases. The hypertext links and nodes that were initially used in the reading stage thus represented a set of knowledge access routes that were analogous to a traditional written text with a linear discourse structure supplemented by footnotes and references (e.g., the theme lists and thematic commentaries). For the Thematic Criss-Crossing Hypertext activity used during the study stage, however, the hypertext linkages between the minicases were frequently *nonlinear* and cut across the different cases. The different theme combinations for Thematic Criss-Crossing Hypertext procedure (Spiro & Jehng, 1990) were used as the basis for generating *multiple virtual sets of links* between the minicase text section nodes. This approach is in sharp contrast to the more common use of *fixed links* to different nodes found in other instructional hypertext design approaches (e.g., Beeman et al., 1987, 1988; Crane & Mylonas, 1988; Jonassen, 1986). During the Thematic Criss-Crossing Hypertext, the restructuring of the link/node relationships between the minicases permitted numerous different traversals of the hypertext minicase knowledge-base by using principled criteria concerning cognitively relevant relationships between the abstract and case-specific components of the knowledge domain. As noted earlier, the theme combinations selected for the Thematic Criss-Crossing Hypertext procedure were predetermined to insure similar coverage of the acquisition materials by subjects in the experimental group. Future research is planned to explore the instructional consequences of learner selected theme combinations and learner created themes.

Minimizing cognitive overload and disorientation in hypertext learning environments. One problem discussed in the hypertext literature concerns possible cognitive overload and disorientation that may occur when using hypertext systems (Charney, 1987; Conklin, 1987; Edwards & Hardman, 1989; Jonassen, 1986; Smith, Weiss, & Ferguson, 1987; Spiro & Jehng, 1990). Another problem involves the possible lack of guidance as to what are the instructionally important facets of the hypertext knowledge base. These problems are minimized with hypertext learning environments employing cognitive flexibility theory design elements, primarily through the use of the *minicase* (Spiro & Jehng, 1990). The learner is given small and cognitively manageable units to study (i.e., the minicase text sections) that still reflect aspects of the domain's conceptual complexity and ill-structuredness. The problem of cognitive disorientation is also managed by using the minicase as the primary hypertext node from which a limited set of instructionally relevant links are available (i.e., theme list, thematic commentary, general theme descriptions, abstract). The learner cannot become lost because she or he is only one link away from any given minicase and the orienting information available from that node, such as the on-line help or a general abstract of the case. (See Spiro & Jehng, 1990, pp. 183-188, for an extended discussion of these and other advantages of using minicases as organizational foci.) Also, important facets of the instructional materials are made explicit through the thematic commentaries, which detail how the abstract knowledge themes are related to the case-specific information depicted in a given minicase text section.

Cognitive flexibility theory and the design of hypertext learning environments. The present study represents the first empirical attempt to evaluate the appropriateness of selected cognitive flexibility theory design recommendations for the development of a hypertext learning environment. Given the superiority of the Thematic Criss-Crossing Hypertext group on the transfer test, the design prescriptions of cognitive flexibility theory for the development of instructional hypertext systems should be further explored. Research could be directed towards different issues related to cognitive flexibility theory hypertexts such as the degree of learner control over case and theme selection, learner developed instructional sequences, different delivery modes for providing expert-like thematic commentary (e.g., written vs. spoken), use of graphical aids to represent complex abstract and case-specific interrelationships, and so forth.

Interaction of Epistemic Beliefs and Preferences and Type of Computer Learning Environment

Earlier work by Anderson and Freebody (1979) has documented the high correlation between scores on vocabulary tests and other measures of verbal and intellectual ability. However there was no significant correlation between the scores on the EBP instrument and the vocabulary test. This finding suggests that the basic beliefs held by a student concerning the nature of learning and knowledge constitute an independent factor from the cluster of cognitive skills generally associated with verbal and intellectual ability. Further research is needed to explore the relationship between general cognitive skill and the learner's epistemic beliefs using additional measures of verbal, intellectual, and academic competence than those employed in the present study.

A significant interaction was found between the EBP of the subjects, the type of experimental treatment they received, and their performance on the problem-solving essay tasks. Whereas these findings should be viewed as exploratory because of the pilot nature the EBP instrument, the overall results of this portion of the study are consistent with earlier research that has demonstrated the influence of an individual's epistemic beliefs on learning (e.g., Feltovich et al., 1989; Schoenfeld, 1983; Schommer, 1990). A component of this interaction was that the subjects with complex EBP who were assigned to the Minimal Hypertext/Drill control condition had transfer essay scores averaged for the two sessions that were significantly lower than the complex EBP subjects in the Thematic Criss-Crossing Hypertext experimental condition. This finding is consistent with the conventional wisdom that regards computer-based drills as being more appropriate for low-level factual memorization. Given the increasing focus of contemporary educational practice to stress higher order thinking and knowledge transfer skills, we feel a finding that students holding a more complex set of epistemic beliefs should learn less well with the long term use of a computer-based drill as not being problematic.

Another, potentially more important, finding was that the subjects with complex EBP who received the Thematic Criss-Crossing Hypertext treatment scored higher on their transfer essay task compared to the subjects with simple EBP who received the same treatment. A likely explanation for this finding is that subjects with simple EBP had difficulty with the nonlinear and multidimensional nature of the experimental hypertext system. Further research could investigate how students with simple EBP can be better prepared to use and learn from an instructional approach such as the Thematic Criss-Crossing Hypertext that employs multiple knowledge representations and nonlinear linkages to demonstrate various knowledge component interrelationships. Other topics future cognitive instructional research could explore are how these epistemic beliefs and preferences might be shaped by particular learning experiences, the degree to which they develop or change over time, and how they might influence learning with different types of technology-based and nontechnology-based learning environments.

Conclusion

This report has discussed research on the transfer of complex knowledge resulting from the use of an innovative theory-based hypertext learning environment. In particular, the demonstration of significant transfer effects that were highly consistent with the study's cognitive theoretical framework is notable given the limited duration of the study. The results of this experiment suggest that an instructional hypertext system that demonstrates critical conceptual interrelationships and the assembly of different case-specific and abstract knowledge components would prepare students to use their knowledge in new ways and in new situations, as shown in the superiority of the Thematic Criss-Crossing Hypertext group on the transfer tests. In contrast, instructional systems that tend to emphasize the acquisition of factual knowledge, such as computer-based drills, may be quite effective at preparing students for tests requiring the recall of factual information. Unfortunately, in this study it was found that subjects who used an instructional computing design of this latter type were less capable of applying their acquired knowledge to new contexts. In addition, researchers may wish to assess underlying epistemic beliefs and preferences held by students concerning the nature of knowledge and learning, given the indication in this study that such beliefs and preferences may enhance or constrain the educational effectiveness of a given type of technology-based learning environment. It is hoped that this research will stimulate further investigation into the cognitive learning processes required to acquire and transfer complex knowledge and the ways technology-based learning environments may be used to assist students in developing rich, interconnected, and usable knowledge in a wide range of domains.

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Table 1

Cognitive Flexibility Theory Instructional Principles and Hypertext Design Features

Theory Principles	Hypertext Features
Reading Stage: Minimal Hypertext/Drill and Thematic Criss-Crossing Hypertext Treatment Groups	
Multiple forms of knowledge representation	Multiple social impact of technology themes and multiple cases
Link abstract concepts to case examples	Theme list and theme commentaries that accompany case presentations
Incrementally introduce complexity	Minicase organizational structure
Study Stage: Thematic Criss-Crossing Hypertext Treatment Group	
Stress interrelated and web-like nature of knowledge	Reread minicases exemplifying different combinations of themes
Explicit demonstration of different combinations of abstract and case-specific knowledge components	Knowledge assembly from different conceptual and case sources

Table 2

Titles and Short Descriptions of the Six Social Impact of Technology Cases

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Case 1: *The Aborted Introduction of the French Electric Car*
The political, economic, and technological successes and failures associated with the attempt to radically alter the social structure of French society during the 1970s through what was intended to be a major innovation: the development and deployment of an electric car.

Case 2: *The UTOPIA Project: Computers Unions, and Printing*
A recent research project known as UTOPIA (which is a Swedish acronym for "training, technology, and products from a skilled worker's perspective") that attempted to allow trade unions a role in the design and implementation of new printing industry technologies.

Case 3: *Jehovah's Witnesses and Blood Transfusion*
The impact on the health-care community resulting from the rejection by the Jehovah's Witnesses of the medical technology associated with blood transfusions.

Case 4: *Privacy and Computer Data Banks*
Personal, legal, financial, social, and ethical issues related to the increasing reliance of modern society on massive computer data bases storing extensive information on millions of people.

Case 5: *High Technology, Automation, and the Worker*
A new generation of highly automated factories provide high productivity and manufacturing quality with low labor costs and pose the question: How long will it be before no people are required in plants of this type?

Case 6: *The Dilemma of the Artificial Heart*
The debate on human subject research employing the artificial heart.

Table 3

Theme and Minicase Matrix for Three Cases of the "Technology and the Twentieth Century: Impact on Society and Culture" Hypertext

Case Title and Section	SOCO	ACNE	PRPR	TEEF	FRCO	COAL
FRENCH ELECTRIC CAR						
Background	x	x				
The Plan	x	x	x	x		x
Technological Predications		x	x			
Implementing the Plan	x	x		x		
Opposition...		x	x			
Technological Problems		x	x	x		
Mirage of Post-Industrial...	x	x	x	x		
End of French Electric Car	x	x				
THE UTOPIA PROJECT						
Project UTOPIA	x	x				x
Technology and Unions	x	x	x	x		
Computers and Printing		x	x	x	x	
The Union's Alternatives	x	x			x	x
Technical Compromises	x		x	x		x
Impact of Project UTOPIA	x	x	x	x	x	
JEHOVAH'S WITNESSES						
Background	x	x	x		x	x
Health Community...		x		x	x	
Medical Care...		x			x	x
Alternative Blood...	x		x	x		
Conclusion	x					x

Note: SOCO = Socially Constructed Nature of Technology; ACNE = Actor Networks; PRPR = Progress-Problems; TEEF = Technological Efficiency; FRCO = Freedom-Control; COAL = Community-Alienation.

Table 4

Summary of Major Features of the Control and Experimental Conditions

Condition	"Reading Stage" Features	"Study Stage" Features
Minimal Hypertext/Drill I (Control I)	Read minicases and theme commentaries; note single most important theme for each case	Computer-based drill on theme identification and factual information
Minimal Hypertext/Drill II (Control II)	Read minicases and theme commentaries; note multiple themes for each minicase text section	Computer-based drill on theme identification and factual information
Thematic Criss-Crossing Hypertext (Experimental)	Read minicases and theme commentaries; note multiple themes for each minicase text section	Theme identification; "Thematic Criss-Crossing:" reread different minicases based on various technology and society theme combinations

Table 5

Representative Items from Epistemic Beliefs and Preferences Instrument

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1. Learning works best when students are told exactly what they are supposed to learn and what they have to do. Everything should be made explicit to students. The best way to learn is to read and re-read textual material until you almost know it by heart.

6. I have a strong preference for simplicity and orderliness. Whenever possible, I prefer not to encounter complex concepts in school (although I deal with complexity when I have to).

19. The parts of a whole system tend to be alike (i.e., systems tend to be homogeneous). Uniformity of explanation throughout a system is a very high goal.

22. Learning is essentially an active process in which you acquire the ability to construct understandings to fit new situations by assembling information you have encountered on various occasions in the past.

Table 6

Short-Answer and Problem-Solving Essay Test Scores

	Short Answer		Essay	
Treatment Group	Session 2	Session 4	Session 2	Session 4
Minimal Hypertext/Drill[a]				
Mean	69.71	65.20	7.65	7.24
SD	13.94	16.73	2.87	2.56
Thematic Criss-Crossing Hypertext[a]				
Mean	62.88	56.42	8.41	9.47
SD	13.45	14.65	3.54	2.35

Note: Scores for short-answer questions are percentage correct; scores for problem-solving essays are on a scale of 0 to 14.
[a]$n = 17$.

Table 7

Problem-Solving Essay Scores (Averaged for Session 1 and Session 2) for Experimental Treatment and Epistemic Beliefs and Preferences Groups

Treatment Group	Simple EBP	Complex EBP
Minimal Hypertext/Drill		
Mean	8.22	6.75
SD	1.79	1.89
n	9.00	6.00
Thematic Criss-Crossing Hypertext		
Mean	7.89	10.29
SD	3.25	1.32
n	9.00	7.00

Note: Essay scores scale of 0 to 14; three subjects were not included because of missing data on the epistemic beliefs and preferences instrument.

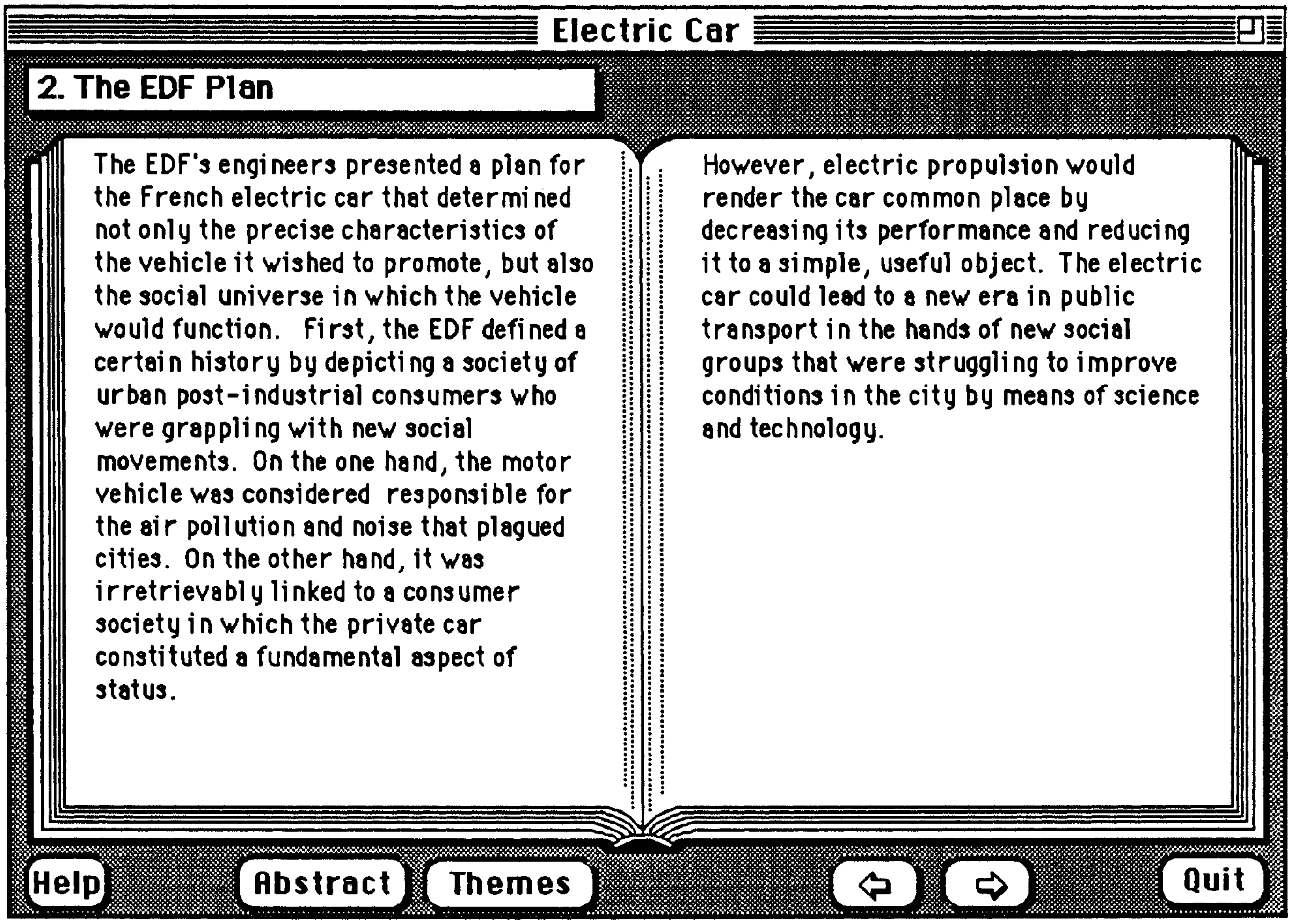

Figure 1. Sample "minicase" text section from the “Aborted Introduction of the French Electric Car.”

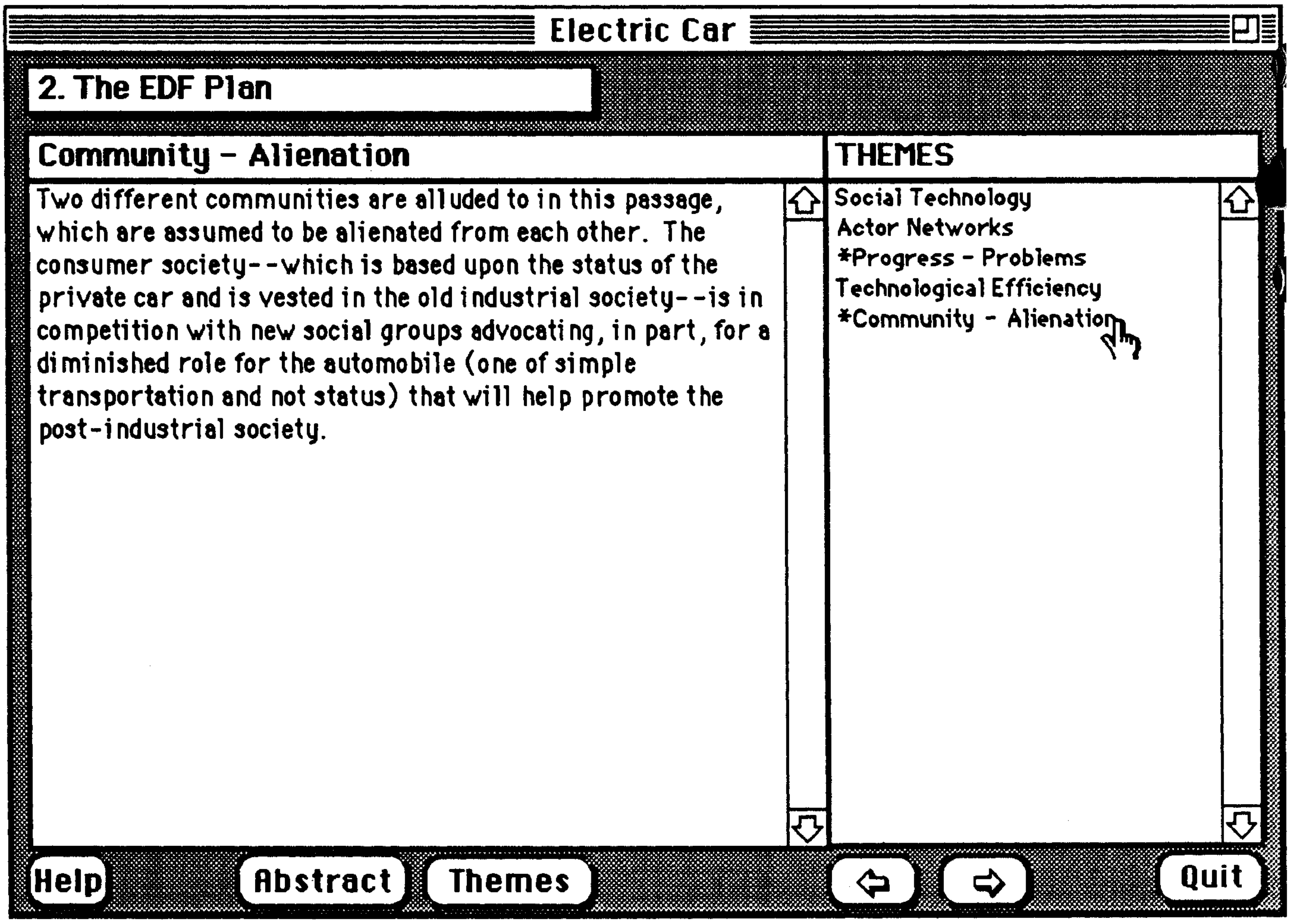

Figure 2. Sample thematic commentary for "minicase" text section from the "Aborted Introduction of the French Electric Car."

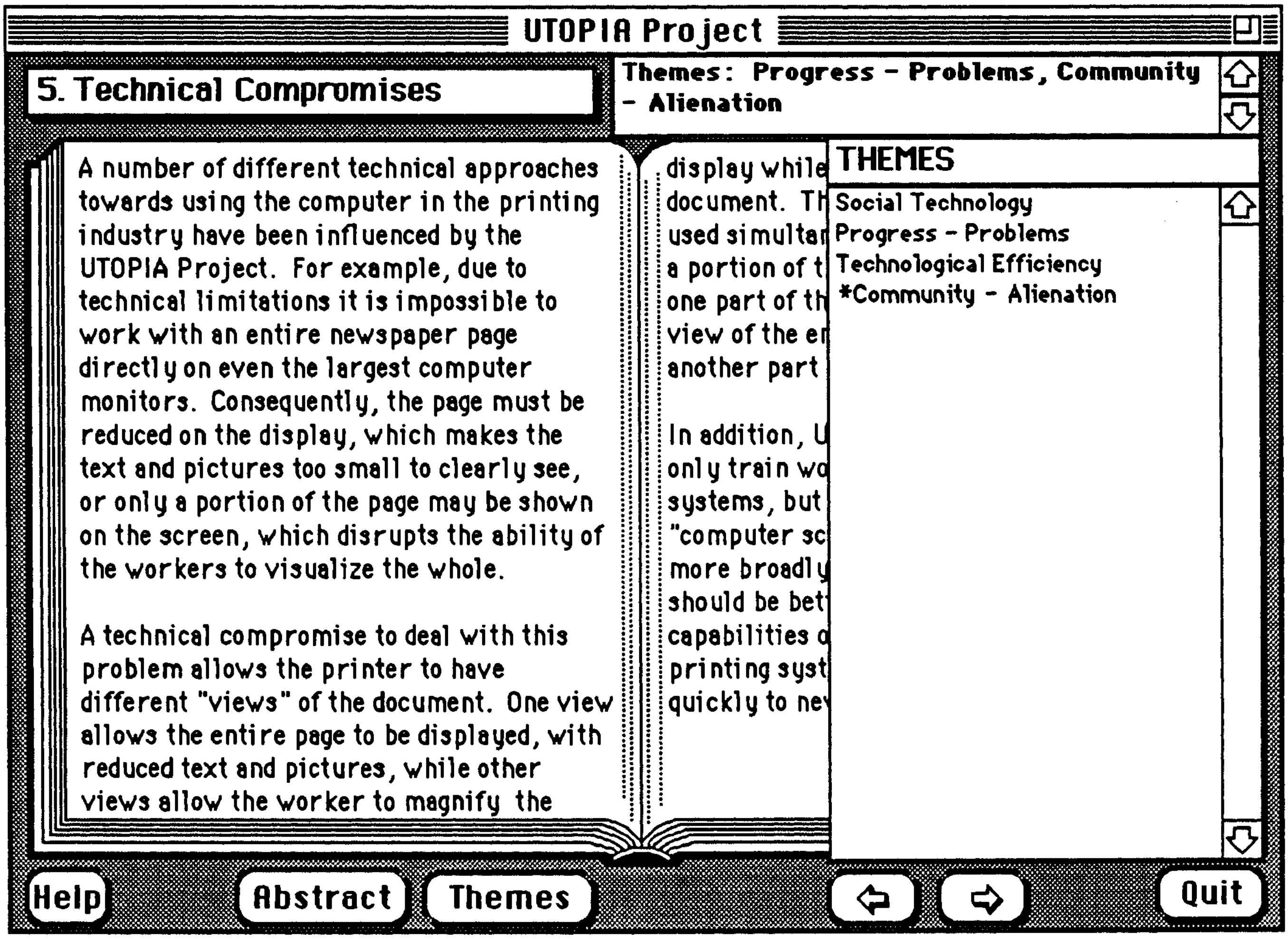

Figure 3. Sample minicase text section from the "UTOPIA Project" showing Thematic Criss-Crossing Hypertext theme combinations and the Theme List.

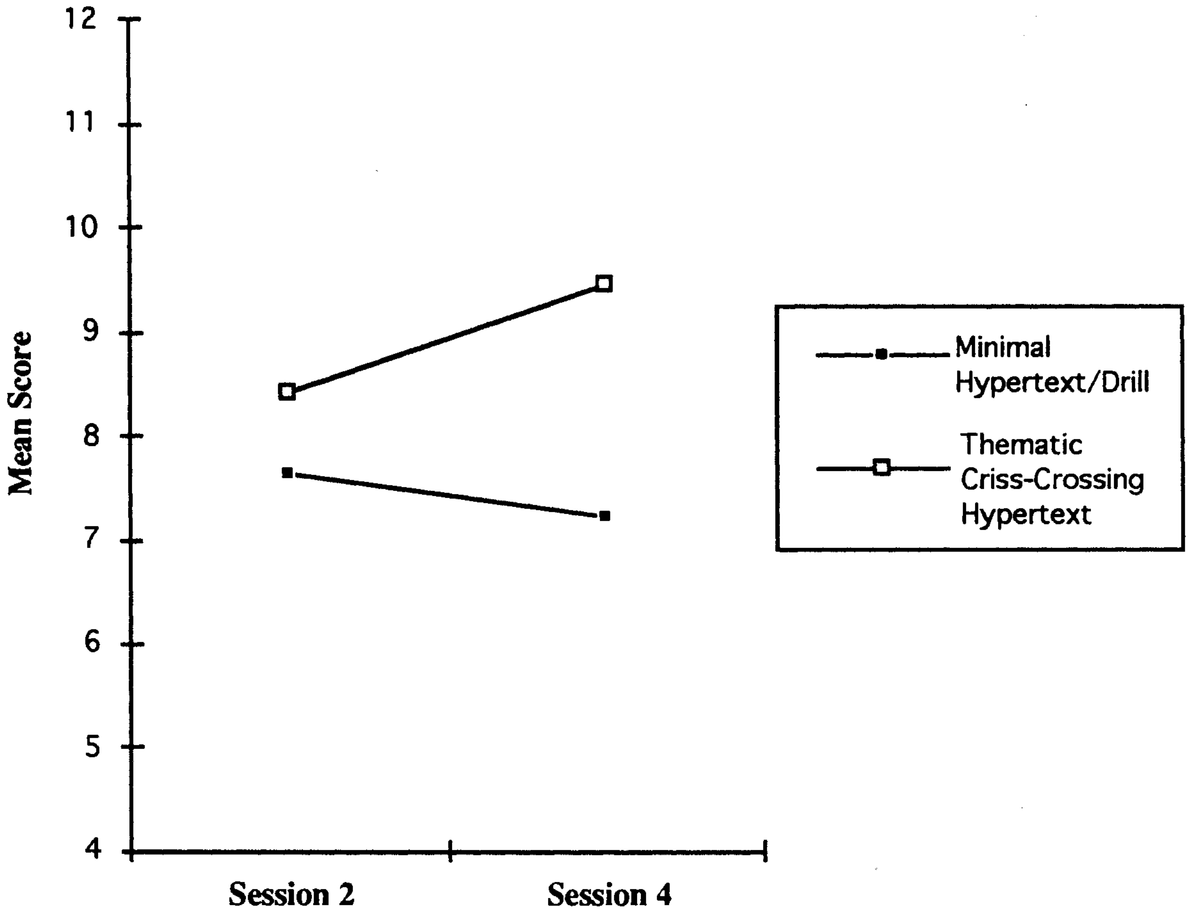

Figure 4. Mean Session 2 and Session 4 problem-solving essay scores for Minimal Hypertext/Drill and Thematic Criss-Crossing Hypertext groups.

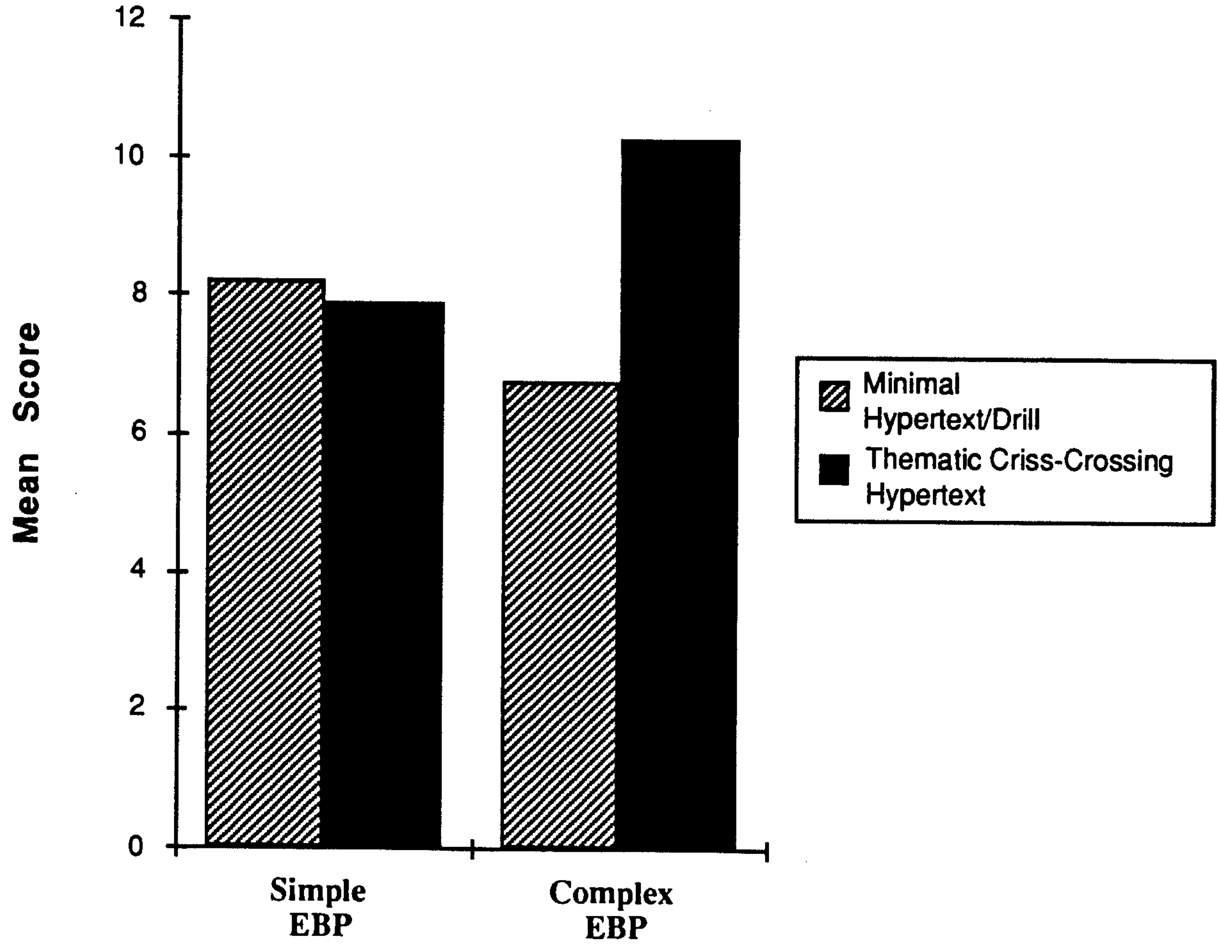

Figure 5. Mean problem-solving essay scores (averaged for Session 2 and Session 4) for treatment and epistemic beliefs and preferences (EBP) groups.

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