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Technology, Representation, and Cognition: The Prefiguring of Knowledge in Cognitive Flexibility Hypertexts

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INTRODUCTION

It is now widely accepted that technology is not neutral with regard to its effects on cognition. By this we do not imply merely that differ-

ent technologies have differing strengths or weaknesses as they relate to thought processes but, rather that different technologies (or media) engender different mind-sets or ways of thinking. Relatedly, many of the characteristics that promote these ways of thinking are *inherent* in the nature of the media and, thus, invisible to the users of these media. In this chapter we shall briefly look at the manner in which different media and representational techniques influence both the processes and the outcomes of cognition. We shall then focus on computer based hypertexts (specifically hypertexts based on Cognitive Flexibility Theory; Spiro, Coulson, Feltovich, & Anderson, 1988/1994) and the kinds of epistemic orientations and conceptual structures that this new theoretical-technological nexus supports: How does that hypertext technology *prefigure* the kinds of cognitive activity that will occur in its users (Feltovich, Spiro, & Coulson, 1989)?

TECHNOLOGY AND COGNITION

The effects of particular technologies on cognition, knowledge, and society at large often are subtle and complexly woven (see, e.g., Salomon, 1979). Strict cause–effect relationships may not be apparent. Moreover, these effects often are not immediately appreciated but, rather, show their influence on far longer time scales—decades or maybe even hundreds of years.

A fruitful way of thinking about the manner in which media influence cognition is that different media *prefigure* cognitive processes and the development of cognitive structures in different ways. In its original usage in the theory of history (White, 1973), a "prefigurative scheme" meant a set of implicit cognitive biases that determine the "ground rules," so to speak, of cognitive processing and analysis (e.g., what kinds of data are important, how they should be evaluated, how arguments should be structured, etc.). White's idea of prefiguration was that it is precognitive and precritical. He argued that prefiguration not only helped delimit the borders of a domain, but also helped determine how concepts will be used to identify the objects in the domain and the nature of the relationships between those objects. All of these attributes are applicable to our use of the term. The important point, again, is that quite often these prefigurative schemes are invisible to the people employing them, but still affect their thinking in essential ways (much like the way the lenses of eyeglasses affect vision without their long-time users being aware at most times that they are looking through them).

PREFIGURING IN WRITING AND PRINT

The idea that the *nature* of media (i.e., not just its contents, not just what it "says," but rather its structure, how it works, what it *does*) influences people's thinking in basic ways is not a new one. Every new technology—from the process of writing to the telephone, from the invention of the camera to the digital computer—has had its share of supporters, who see in it the possible emancipation of humankind, and also its share of detractors, who see in it the death of much of the good that has existed. An ancient argument of this kind can be found in Plato's dialogue, *Phaedrus*, in which Socrates (actually Plato speaking through Socrates) makes the argument that writing (and books) would destroy thought. The crux of the argument is that books merely make statements; they do not argue back. Socrates claimed that this passivity would undermine reflective thought—the ability to think deeply about things, to question and examine every assertion. The crucial concern for Socrates was not *what* people would write, but rather, the effects of the print medium itself, on the fundamental nature of thinking. The technology of writing (and print that followed it) changed our view of the world. Writing today is so ubiquitous, so much a part of our world, that it is difficult, if not impossible, to imagine a solely oral culture. Knowledge in such cultures would be more fluid; it could change radically with every retelling. This would be in radical contradistinction to the notion of immutable, absolute, ever-available authority that is associated with certain texts in print culture.

The invention of movable type and printing in the fifteenth century was responsible for creating an intellectual revolution that impacts us even today. In contrast to Socrates, who focused on what was lost through the process of *writing* (specifically its effect on argument and dialogue), others have proposed that it was the advent of the printing press that made a wide variety of intellectual options possible (Bolter, 1990; Eisenstein, 1980; McLuhan, 1962, 1964; Ong, 1982; Provenzo, Jr., 1986). Indeed, the invention of printing was followed by a series of dramatic changes in all aspects of social, cultural, political, and scientific life in Europe and, from there, the rest of the world. For example, it solidified the notion of ownership of ideas and the convention that arguments could be decided by invoking the appropriate text (although it is notable how greatly these basic assumptions have been undermined recently; e.g., Feltovich, Spiro, Coulson, & Myers-Kelson, 1995).

Most of the significant effects of the invention and spread of print can be traced to certain specific properties of print media: In par-

ticular, print created objects that were *mobile, immutable, presentable, and readable;* and these properties led to fundamental changes in human cognition (Latour, 1990). These properties ensured (or seemed to ensure) that discussions could be carried beyond the conversational arena, that ideas could be transported without change in their essential nature, and that they could be universally and *consistently* understood (at least by those who knew the conventions) in a way that more mutable, "unreliable" oral retellings could not. The crucial argument here is that initially it was the medium, this new fixed object, that was immutable. Then the idea of immutability passed on from the medium to the message, with attendant implications of accuracy, fixedness, and truthfulness. Thus, print, by its very nature, prefigured the manner in which discourse could be, and was, structured. As Delany and Landow have stated

> The written text is the stable record of thought, and to achieve this stability the text had to be based on a physical medium: clay, papyrus, or paper; tablet, scroll or book. But the text is more than just the shadow or trace of a thought already shaped; in a literate culture, the textual structures that have evolved over the centuries *determine* thought almost as powerfully as the primal structure that shapes all expression, language. So long as the text was married to a physical medium, readers and writers took for granted three crucial attributes: that the text was *linear, bounded, and fixed.* Generations of scholars and authors internalized these qualities as rules of thought, and they had pervasive social consequences (Delany & Landow, 1991, p. 3).

COMPUTER-BASED HYPERTEXT AND COGNITION

Hypertext systems, both as knowledge access and storage systems, and as learning environments, have been attracting considerable attention recently (e.g., Landow, 1992; Spiro & Jehng, 1990). The term *hypertext* refers to computer based information systems that are characterized by their mutability: They can be "restructured" along different dimensions, for different purposes, at different times. As such, they are distinguished from other media by the extent to which they engender *nonlinear* and *multidimensional* explorations of their content. Hypertext has the ability to produce large, complex, richly connected, and cross-referenced bodies of information in a number of different forms (text, graphics, audio, video as well as other kinds of data). Often, the term "hypermedia" has been used to refer to systems containing multiple media repre-

sentations. That term has been used interchangeably with "hypertext." We prefer the latter term, which conveys the sense of *text* as any object of study that affords rich interpretation (as it is used, for example, in poststructuralist theory; e.g., Barthes, 1970).

Just as every new technology imposes its own constraints on the communication process (as well as providing new opportunities), hypertext systems do so as well. Our concern here is not so much the content of these systems, but rather how their *form* influences the cognitive structures and processes of those who use them. In contrast to the linear, bounded, and fixed nature of printed text, computer-based hypertexts are nonlinear, unbounded, and dynamic. For example, they make possible fluid and nearly unlimited juxtaposition and linkage of elements, without regard to the physical location of the elements (in contrast to conventional text). We will now begin to address the cognitive consequences of these characteristics of hypertext, especially as they bear on two issues: (1) the use of hypertext to promote learning; and (2) the design of hypertext to optimize flexibility and knowledge usability in learning.

LEARNING THEORY AND EDUCATIONAL GOALS IN THE CONTEXT OF HYPERTEXT: COGNITIVE FLEXIBILITY AND ADVANCED KNOWLEDGE ACQUISITION

The raw capabilities of hypertext, for example, the ability to provide links to different information nodes, are not sufficient to insure that they will be effective as learning and teaching devices. Two main problems have been identified with the design of hypertext learning systems (e.g., Spiro, Feltovich, Jacobson, & Coulson, 1991a; Spiro & Jehng, 1990): (a) the lack of a sound theoretical framework to guide the enterprise—too much hypertext development has been technology-driven rather than theory-driven; and (b) the neglect of what cognitive science and educational psychology have to say about learning. If computer-based systems will inevitably change the way in which students think, the new media technologies have to be structured so that these changes will be beneficial. For this to happen, designers should have guiding principles about what kinds of cognitive change are desirable and how using the systems will effect those changes in students. In this chapter we will consider the following learning outcomes to be desirable ones: Students should be able to go beyond merely memorizing facts to the formation of a deeper understanding of important but complex knowledge, and

they should develop an ability to use that knowledge in new situations (i.e., knowledge transfer). To accomplish these goals, learners should cultivate multifaceted and flexible knowledge representations that can be used in many kinds of situations and contexts. These learning goals have been referred to as being those of "*advanced knowledge acquisition*"—learning beyond the "introductory" stage for some subject matter (Spiro et al., 1988/1994).

A step toward formulating a theory of advanced knowledge acquisition has been taken by the developers of *Cognitive Flexibility Theory* (Feltovich et al., 1989; Spiro et al., 1988/1994; Spiro, Feltovich, Coulson, & Anderson, 1989; Spiro, Feltovich, Jacobson, & Coulson, 1991a,b; Spiro & Jehng, 1990; Spiro, Vispoel, Schmitz, Samarapungavan, & Boerger, 1987). They have argued that effective learning in complex and ill-structured domains cannot be achieved by utilizing or building rigid, single-purpose schemas. Inflexibly prepackaged knowledge structures are useful for situations that match those in which learning took place. However, in most domains that require application of knowledge to naturally occurring situations, inflexible, precompiled knowledge structures are a hindrance. Just as one can never cross the same river twice, quite often when one approaches a new situation in a complex knowledge domain a new set of "intellectual tools" have to be assembled for the particular situation at hand. Flexible cognitive representations enhance the transfer of knowledge to contexts different from those that had been involved originally in the teaching of the material. Such representations increase the likelihood that knowledge *ensembles* can be *constructed* as required. Rigid schemas often are artificially induced generalizations from individual cases, whereas what is needed instead is to determine patterns in the way general principles work across different cases and situations. Spiro et al. (1987) offer the metaphor of "criss-crossing a landscape" from many different directions as a way of learning about complex domains (see also, Wittgenstein, 1953).

> The best way to come to understand a given landscape is to explore it from many directions, to traverse it first this way and then that (preferably with a guide to highlight significant features). Our instructional system for presenting a complexly ill-structured "topical landscape" is analogous to physical landscape exploration, with different routes of traversing study-sites (cases) that are each analyzed from a number of thematic perspectives.
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> The notion of "criss-crossing" from case to case in many directions, with many thematic dimensions serving as routes of traversal, is central to our theory. The treatment of an irregular and complex topic

> *cannot be forced in any single direction* without curtailing the potential for transfer. If the topic can be applied in many different ways, none of which follows in a rule-bound manner from the others, then limiting oneself in acquisition to, say, a single point of view or a single system of classification, will produce a relatively *closed* system instead of one that is open to context-dependent variability. By criss-crossing the complex topical landscape, the twin goals of highlighting multifacetedness and establishing multiple connections are attained. . . . *Information that will need to be used in a lot of different ways needs to be taught in lots of different ways* [italics in original; Spiro et al., 1987, pp. 187–188].

In today's complex world, such flexible approaches to knowledge acquisition and application are essential. Our claim is that to achieve these kinds of goals, certain fundamental ways of thinking must be changed. We argue that hypertexts based on Cognitive Flexibility Theory not only change the kinds of specific knowledge structures built for a topic, but also change the *kind* of thinking people do (in ways that will be illustrated throughout the next section). These changes in the manner of thought do not result from telling learners what they should do, but rather from the way the hypertexts are designed and built—the theory of cognition is designed *into* the medium and the requirements for its use.*

In the next section we shall discuss some of the specific theoretical tenets of hypertext systems modeled on the principles of Cognitive Flexibility Theory. We will describe the manner in which such systems *prefigure* the shape of knowledge and cognitive processes, and thereby enhance the ability of learners to flexibly assemble situationally appropriate knowledge "complexes" from a variety of knowledge sources.

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*A possible misunderstanding of our approach is that we take ill-structured subject matter and impose order on it through its inclusion in our hypertext systems. This is not the case. As will become evident later in this chapter, the characteristics of knowledge domain complexity and ill-structuredness are not only retained in the hypertexts, they are given special *prominence*. So, the knowledge domain (landscape) remains ill-structured; hypertexts based on Cognitive Flexibility Theory are structured to be vehicles for helping learners grow into being able to handle this kind of complexity in a sophisticated way. (Of course, local regions of greater orderliness can also be detected within the larger complexity that is provided. Also, for domains that are more well-structured as a whole—and there are far fewer of these than one might imagine—traditional media might perhaps be more efficient in promoting knowledge acquisition.)

PREFIGURATION IN HYPERTEXTS BASED ON COGNITIVE FLEXIBILITY THEORY

There are a large number of ways in which Cognitive Flexibility Theory (CFT) structures hypertexts differently from other hypertext systems. Some of the significant attributes of the CFT hypertext approach, with particular emphasis on the manner in which they prefigure the kinds of knowledge structures and processes created by students, are described in the following. (The discussion will be at a general level, concerned with theoretical issues. For specific details on CFT hypertexts see, e.g., Spiro & Jehng, 1990; Spiro et al., 1988/1994.)*

Multiplicity

Hypertexts developed in accord with CFT have at their core the idea that learning and knowledge acquisition are better achieved when students develop *multiple representations* and interpretations of the domain under consideration. Unitary explanations, though simpler to teach and learn, often misrepresent crucial facets of complex, ill-structured domains (Feltovich et al., 1989; Zook & DiVesta, 1991).

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*Prototype hypertexts based on CFT have been developed in a variety of domains, ranging from high school biology to military strategy; film criticism to cardiovascular medicine. In general, they all share certain features. Screens present options for various kinds of explorations. The options always include a case-by-case reading or a theme-based traversal across cases. For example, in the domain "twentieth century social and cultural history," one might choose to read a case about the automobile, or one about aspects of modern art. Or one could request a display of just those parts of the various cases that illustrate one of the multiple conceptual themes for the domain (or some combination of them). So, considering a possible multi-thematic traversal, it might become interesting for a student at some stage of learning and in some educational setting (all of the uses of the hypertexts are intended to be situated in some meaningful task context, e.g., answering an essay question or solving a problem), to see how the theme of "fragmentation in modern society" intersects with the theme of "rapid change," across cases that have an economic emphasis. After the student selects these options with a few clicks of a mouse button, the hypertext would then re-edit its text and image base to show just those cases and case segments that were pertinent to all of the three selected perspectives. In essence, the highly multidimensional thematic space is used to construct diverse criss-crossings of the topic—multiple text organizations of the same content material that each serve their own unique instructional purposes in illuminating different views of the domain's multifacetedness. Again, this is just the most skeletal of overviews of a highly complex approach to hypertext design that has many theory-based features—the interested reader will find ample detail in the cited papers.)

Multiple representations, however, expose people to the contextual and situational differences in how these representations should be used and can emend the deficiencies of single representations (Spiro et al., 1989). Computer based hypertexts can harness a variety of media sources such as video, photographs, graphs, and diagrams, thus allowing the computer to take on the strengths (and differing symbol manipulations capabilities) of different media. Combining text with graphics and video can lead to an experience that combines the analytic/reflective modes of thinking with the spatial and temporal modes. However, CFT hypertexts go beyond such straightforward multimedia capabilities. CFT hypertexts promote the use of multiple *conceptual* knowledge representations, such as multiple analogies, multiple themes, multiple points of view, and multiple lines of argument (e.g., Spiro et al., 1989). The multiplicity of representational schemes prevents the easy adoption of single and monolithic explanations.

Summary: prefiguration of multiplicity (the limitations of single representations and the importance of multiple representations)

Providing learners with the possibility of adopting multiple representations (conceptual and modal) and structuring the content matter such that it they can form multiple interconnections prefigures the technology-content-learner triad in certain specific ways. Students who have used this kind of system will be more skeptical of unitary, and "all-purpose" generalizations. They will realize that relying on a single *conceptual* viewpoint (argument, analogy, organizational logic) is incomplete and merely leads to a partial understanding of the domain. Moreover, using multiple media and representational formats should open learners to different ways of learning—rather than restricting them to the analytic/reflective mode so emphasized by the linear print media.

Complexity

A variety of misconceptions or biases in learning and understanding of complex subject matter that students bring to the classroom have been identified (e.g., Feltovich, Spiro, & Coulson, 1993; Feltovich et al., 1989; Spiro et al., 1988/1994, 1989). These authors have argued that these misconceptions develop in part because of simplifications that are imposed on complex and irregular subject matter at early stages of learning. These simplifications, although

intended to ease and aid understanding, actually hinder the acquisition of advanced understandings and prevent the development of flexible cognitive structures that will help students apply the knowledge in new situations (Feltovich et al., 1989; Spiro et al., 1988/1994, 1989). Most previous learning theories have advocated incrementally increasing the complexity of the subject matter with increasing student experience. However, often this does not work out as intended: Students often become fixated with the simplistic models or overly reduce the more accurate, more sophisticated models in the direction of the simplifications (e.g., Feltovich et al., 1989). In contrast, CFT proposes the idea of confronting the student at the very beginning of instruction with selected, small-scale cases — bite-sized chunks of complexity as it were (Spiro & Jehng, 1990). These "mini-cases" are chosen to be illustrative of the features of complexity or irregularity of the domain to be learned at large (e.g., they illustrate the importance of multiple rather than single representations), yet they are "small" enough not to overload the student's cognitive processing capabilities—they are cognitively manageable staging grounds for the introduction of complexity. This "*new incrementalism*" of CFT emphasizes the spiral-like development of knowledge by the gradual increase of the number and size of specific cases and the ideas that link across them, thus progressively bringing out the "contours" of the complex topical landscape. (This contrasts with the "old incrementalist" sequencing logic of beginning with simple presentations that lack the most important features of complexity and thus induce epistemic expectations in learners that leave them unprepared for later, more in-depth treatments of the content.)

Summary: prefiguration of complexity

The introduction of complexity at the initial stages of the instructional process (albeit in manageable chunks) guards students from being seduced by or seeking inappropriately simplistic interpretations and understandings in complex and ill-structured knowledge domains. Students are exposed to the limitations of "first-pass understandings" and are made more aware of such things as the existence of exceptions to "rules" and the deceptiveness of superficial similarities.

Context-dependency

CFT hypertext systems are based on the idea of developing abstract concepts through the exploration of their application in the direct

context of different case examples, so that the need for tailoring of abstractions to their contexts of application is highlighted. It is the nature of complex and ill-structured domains that abstractions, rules, principles, and the like, do not retain absolute, context-independent meaning. Rather, their meaning is highly content-sensitive and must be tailored to the particulars of situations. CFT hypertext systems enable learners to explore instantiations of concepts across numerous different case contexts, experiencing the nuances of change in conceptual meaning that occur. Information no longer remains an abstract, decontextualized static "thing-out-there," but is seen to be embedded within a context. Facts do not remain self-evident, isolated bits of information, but rather, are "constructed" by their perceived relationship to other facts and by their usefulness in understanding cases. The meaning of facts and concepts will shift as the criteria for associating them with other facts and concepts in interpreting cases change. Thus, the meaning of concepts, ideas, and facts become contingent on the nature of the questions being asked, the nature of relationships being investigated, and so on.

Summary: prefiguration of context-dependency

CFT hypertexts emphasize critical thinking skills in students. Critical thinking relies, among other things, on relating things to one another—determining relationships among different topics and ideas. However, determining these relationships is not a matter of "connecting anything with anything else." What is needed is a rationale to seek and find these connections, to put forth tentative hypotheses, and to seek further information to build on them or to reject them. CFT hypertext (with its framework of cases and broad thematic, conceptual descriptions) structures the interaction with the student along exactly these lines. By emphasizing the creation of knowledge by studying the variable interplay between cases and broad thematic ideas, CFT hypertexts emphasize to students the limitations of strictly abstracted, "top down," overly conceptually driven processing. They become more involved in teasing out the meanings of concepts as they are applied to specific cases, rather than trying to generate a simple rule or abstracted meaning that explains everything. They begin to pay more attention to *tailoring* their understandings to the given situation to which their knowledge is to be applied, rather than seeing cases/examples as mere instances of some universally applicable abstract idea that they are to grasp. Concepts become less deterministic, working differently in different situations and contexts, rather than being rigid constructs that can dictate some "right

answer." The learning of a concept is achieved not in a way that is like reading a dictionary definition but, rather, by seeing it used in a variety of contexts and settings, ("Conceptual Variability and "Openness" in Conceptual Structures"). CFT hypertexts, by supporting the linkage and tailoring of concepts to practice (actual case examples), enhance the development of context-sensitive, adaptable knowledge structures.

Interconnectedness

By utilizing a large variety of exploration routes across the many cases and conceptual themes in a CFT hypertext, learners develop a sense that there are many ways to traverse some body of knowledge but *no single path* that is sufficient for achieving understanding. This is because CFT hypertexts undermine the standard, rigid classification of concepts and ideas that is exemplified in the organization of chapters of textbooks. Such a classification inappropriately conveys the idea that knowledge can be compartmentalized in discrete and predetermined (and usually hierarchical and nested) knowledge structures. In contrast, in a CFT hypertext the relationships and organizations among topics are multiple and evolving. Tendencies toward strict hierarchical and compartmentalized structuring are subverted in favor of structuring that emphasizes the overlapping, entangled, "web-like" nature of knowledge, with a multiplicity of possible connections among cases and concepts, and fluid systems of classification (Feltovich, Coulson, Spiro, & Dawson-Saunders, 1992).

Summary: prefiguration of interconnectedness (noncompartmentalization and multiple interconnectedness in knowledge organization).

Built into CFT hypertexts is an emphasis on the web-like nature of knowledge, reflecting the "messiness" of the world of knowledge use and avoiding the essentially false distinctions often drawn between subject areas. Concepts have differently configured applications across different cases and are not split apart into separate "chapters." Classifications of objects and situations change in different circumstances. Thus, irregularity in classification within complex, ill-structured domains is highlighted and the need for situation-based reclassification of knowledge elements is made salient and modeled. What becomes important is *intertextuality*—the ability of "texts" (including graphics, movies, etc.), and their component parts, to refer to each other in complex ways, supporting, ignoring, or denying the meanings of other

texts according to context. By emphasizing the "fuzziness" that exists in the manner in which concepts and other abstractions are applicable, learners become attuned to seeking "family resemblance" forms of meaning (Wittgenstein, 1953), rather than a single, highly specified understanding that is applied universally, and multiple, flexible processes of classification rather than strict processes of compartmentalized classification.

Inexhaustibility of Understanding

CFT hypertexts make it clear that cases, concepts, and ideas can, at different times, be harnessed to support different concerns and points of view. Thus the beginning learner is "primed" to appreciate the subtle nuances of differences in "truth" across different cases, under different conceptual interpretations, according to different objectives, and so on. In this regard, CFT promotes the *"revisiting"* of cases and thematic explorations (as well as thematic commentaries) as circumstances or the learner's knowledge and appreciation change. It must be emphasized that revisiting is not the same as repeating (Spiro et al., 1991a). Simple repeating is boring (and not greatly beneficial to learning), whereas revisiting contains the excitement of seeing the same thing with a new and different set of "lenses," for example, recently acquired experiences or new points of view. Revisiting is important not only to bring out the multifacetedness of cases (that is hard to grasp on any single reading, in any single context), but also to bring out the manner in which different cases and thematic interpretations "change" with changes in experience or perspective. (This realization is facilitated in CFT hypertexts by the use of "context-sensitive selective highlighting" of relevant portions of the learning material: Depending on the recent context of hypertext exploration by the learner, different elements of the material currently under view are graphically accentuated.)

Summary: prefiguration of the inexhaustibility of understanding

Users of CFT hypertexts realize that learning does not mean merely adding something new to what existed before; it means changing the way we think about the things we "knew" before that are connected to it. Learning does not just build on what is already known, it affects what was previously encountered in intricate and fascinating ways. This process of revisiting earlier sites of learning from the perspective of new contexts and purposes elicits

a mind-set of knowledge questioning and renewal. There is always more that can be learned, seen, and appreciated in any rich case of knowledge application and understanding, and this is accomplished by adopting a new attitude to the *revisiting* of material; the required attitude is that a revisitation is more of a "new view" than a repetition.

"Openness" in Conceptual Structures

CFT hypertexts provide a set of organizing principles within which to structure the learner's engagement with the given domain, but these are loose guides rather than closed, highly denotative structures (Spiro et al., 1991b; Spiro & Jehng, 1990). Conceptual themes are provided for the student, but the way the hypertext is used makes it repeatedly clear (e.g., through theme-search options) that their meaning changes in important ways across different contexts of application (across different cases). The student realizes that, rather than a common core of meaning across the various uses of the concepts, those uses are linked only by overlapping patterns of family resemblance (Wittgenstein, 1953)—the conceptual structures are nothing more than rough starting point for thought, subject to processes of interpretation and tailoring to the specific details of the case at hand. The structure of the hypertext, without prestored links, yet allowing for a set of broadly gauged themes or ideas for guidance in criss-crossing, allows students to recognize the unique and individual nature of individual cases even while seeing them as being the results of the dynamic interplay of conceptual themes and case particulars. This militates against the temptation to try to build universally applicable, rigid knowledge structures, while allowing learners to become actively engaged in the more fluid, context-dependent production of meaning. So, something *is* provided to subjects, a seemingly unconstructive practice; however, what is provided are open structures to help one start in one's construction of new knowledge, rather than closed structures that restrict constructive activity. (Also, the student is free to go beyond the presented information, to develop further cases, principles, and conceptual themes.)

Summary: prefiguration of "openness" in conceptual structures

CFT hypertexts put students in charge of the task of their own meaning-making, but also give them a *compliant* guiding framework within which to work (Spiro et al., 1991b). Knowledge in

complex and ill-structured domains is difficult to "hand down" or precodify. CFT hypertexts are designed to make students less dependent on explicit transmission of knowledge from an authority (either in the form of a teacher or a textbook). However, CFT hypertexts do not leave students "out in the cold." They show students the contributions that can be made by expert knowledge and how experts can be used as consultants (within the CFT hypertext itself) in understanding problems or situations. Thus, learners see that it is neither the case that knowledge is a fixed and given thing, nor that there is no role at all for being guided by conceptual structures. Rather, one *constructs* knowledge based *partly* on *open* and *flexibly adaptive* knowledge structures that are provided as *starting points* for the students.

Adaptive Flexibility

The main aim of CFT hypertexts is to help students acquire flexible cognitive skills that can take multiple, interrelated concepts and *apply* them to new, diverse, and largely unexpected circumstances (rather than confining students to the simpler capabilities of recalling how something was taught and then applying it in roughly the same way). This is of great importance in advanced learning situations that require complex and interdependent conceptual applications that differ in the particulars of application from context to context. It is this stress on the achievement of knowledge *transfer* rather than knowledge retention, on the development of situation-specific knowledge assembly rather than generic schema retrieval, that is the most essential goal for learners as they work with CFT hypertexts. Knowledge cannot be applied indiscriminately to new situations but must be assembled for application, with guidance from prior experience, from various acquired conceptual and case sources, and from the case at hand.*

*Although we do not consider the findings to be definitive yet, early studies have provided a preliminary indication that the "criss-crossing" instructional approach based on Cognitive Flexibility Theory leads to improved transfer of knowledge to new situations. Reflecting a similar pattern found in other experiments are the results of Jacobson & Spiro (1995). In that study, subjects were randomly assigned either to an experimental condition that used hypertext that permitted a nonlinear, theme-based traversal of cases in the domain of "science, technology, and society," or they were assigned to control conditions that required more linear reading of the *same* content that the experimental condition read (also presented

Summary: prefiguration of adaptive flexibility

In a sense, this emphasis on transfer of knowledge lies at the core of Cognitive Flexibility Theory. By focusing on the building of certain kinds of flexible cognitive structures and processes, CFT aims at instilling a certain philosophy of learning and education. This philosophy aims at making understanding interesting and fun for students without forsaking the inherent challenges in understanding difficult concepts and ideas. It aims to create more open-minded and flexible students, students who are independent, adaptive, original thinkers. These students are not likely to accept broad generalizations easily, are likely to be skeptical about issues, and likely to be sensitized to the contingency and context-dependency of ideas. They should respect expertise but not be overawed by it. They should be ready to tackle new situations, bringing to them not rigid preconceptions, but rather, rich, complex understandings selectively constructed for the present situation from previous encounters with associated cases and relevant concepts.

CONCLUDING REMARKS

Various themes of Cognitive Flexibility Theory and associated principles of hypertext design have been presented in the context of a set of goals of advanced knowledge acquisition in complex domains. The point of this chapter is that these goals can be accomplished partly through having the identified "learning values" (e.g., the importance of multiple representations; context-dependency; inexhaustibility of understanding) *prefigured* in the structure of the technological medium itself—the learner not only discovers specific

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on the computer). Subjects in the control condition had a higher mean on tests of factual memory for the presented material. Apparently, a single, orderly scaffolding for material facilitates reproductive memory. However, the experimental condition, which effectively employed multiple organizations of the same material (i.e., the kind of "criss-crossing" of a topic's conceptual landscape that is at the core of Cognitive Flexibility Theory), scored significantly higher than the controls on a test that required *application* of the presented material to a new situation (a problem-solving essay involving a totally new case). The nonlinear and multidimensional approach seems to produce the intended transfer of instructed knowledge to new situations. (Again, we believe further empirical research is required to definitively demonstrate this conclusion across a range of contexts.)

things about some subject matter when using the hypertext medium (that are, of course, themselves structured to support the cognitive goals of CFT), but also assimilates fundamental presuppositions about the nature of knowing, coming to know, and using what one knows. At a general level, it is hoped that the prefigurative influences built into these hypertexts will help to replace habits of mind that might be simplistic, rigid, and passively receptive to authority, with views of the learning enterprise that acknowledge complexity, are more flexible, and that privilege the constructive processes of the learner.

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