COGNITION, EDUCATION, and MULTIMEDIA: Exploring Ideas in High Technology

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Cognitive Flexibility and Hypertext: Theory and Technology for the Nonlinear and Multidimensional Traversal of Complex Subject Matter

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Traditional methods of instruction rely on linear media (e.g., textbooks and lectures). Linearity of media is not a problem when the subject matter being taught is well structured and fairly simple. However, as content increases in complexity and ill-structuredness, increasingly greater amounts of important information are lost with linear approaches and the unidimensionality of organization that typically accompanies them. The advent of random access computer technologies makes practicable new forms of nonlinear and multidimensional learning and instruction that are better suited to conveying complex content. For example, it becomes a straightforward matter to revisit the same content material in a variety of different contexts, with each visit bringing out additional aspects of that content's complexity that are missed in the single pass of linear coverage. We use the expression random access instruction to refer to a cluster of fundamental issues brought into play by nonlinear learning with random access media. This chapter discusses a unified theoretical approach to those fundamental issues, an approach that provides a foundation of principles to guide random access instruction.

The research discussed in this chapter illustrates aspects of a general theoretical orientation to knowledge acquisition and application in complex content domains, Cognitive Flexibility Theory (Spiro, Coulson, Feltovich, & Anderson, 1988; Spiro, Vispoel, Schmitz, Samarapungavan, & Boerger, 1987). We argue for the suitedness of this theory to the special needs of
random access instruction. The generality of the theory is attested to by the fact that it has been applied in roughly the same way to such diverse areas as literary comprehension and interpretation, biomedical cognition, history, and military strategy (Feltovich, Spiro, & Coulson, 1989; Spiro, Feltovich, Coulson, & Anderson, 1989; Spiro et al., 1987; Spiro et al., 1988; Spiro, Feltovich, Coulson, Jacobson, Jehng, & Ravlin, in preparation).

Although this chapter is primarily concerned with the application of theoretical issues of advanced learning on complex topics to a particular instructional approach, there is also a focus on one illustrative context for that discussion: a computer program in the area of literary comprehension and the understanding of complex patterns of individual behavior. Again, however, the chapter has a general theoretical point, it is not limited to the one area chosen to illustrate the theoretical concerns.

Because the meaning of literary works transcends the mere chronicling of the events they contain and also tends not to be reducible to any single interpretation, representation of patterns of thematic deployment often forms the most useful scaffolding for their comprehension (rather than a single event-oriented schema). A literary work usually contains many themes and symbolic structures. A given theme is likely to be used in diverse ways, be relevant at irregular intervals throughout the work, and form intricate patterns of combination with the other themes. We argue that mastery of complexities such as these, which are found in all rich content domains, is greatly facilitated by the kind of guided nonlinear and multidimensional explorations typified by the instructional program (based on Cognitive Flexibility Theory) discussed in this chapter. (Furthermore, we have accumulated considerable evidence that more advanced understandings of this kind very frequently not to be successfully attained in typical instructional settings—see, e.g., Feltovich et al., 1989; and Spiro et al., 1988; Spiro et al., 1989.)

The project that is the primary focus of this chapter uses a random access (i.e., interactive, programmable) videodisc of the complexity structured classic film Citizen Kane (Welles & Stein, 1984). A large number of short segments drawn from several scenes of the film have been closely analyzed for their patterns of instantiation of the film's thematic and symbolic structure. This analysis forms the basis for a very large number of computer-generated re-editings of the segments as a function of their patterns of thematic relatedness. In one use of the program, after students/subjects see the full scenes in their natural sequence, they are then exposed to variously rearranged traversals of the scenes in different contextual arrangements. Commentary is appended explicating the thematic and symbolic contrasts illustrated by each traversal (i.e., each thematically based re-editing of the scenes).

This use of programmable video to construct multiple "texts" is intended to prepare learners (better than instruction with a standard linear schema for the film would) to go beyond the ability to merely reproduce the instruction they received, and instead to be able to independently apply the instructed knowledge to new situations that differ in their characteristics from those of initial learning. That is, the goal is transfer. An example of a transfer goal that the program is intended to facilitate is an improved ability to comprehend scenes from the film that have not yet been seen. Or the knowledge acquired from instruction should serve more effectively as background knowledge to support the comprehension of critical texts written about the film. It is also hoped that more general transfer might occur: by having the need for complex analysis of literary works clearly demonstrated to students, they will be more likely to avoid typical tendencies toward oversimplification in other literary works; and by fostering skill in the processes of complex text-based interpretation, the students should be better able to carry out the more complex analyses of new works. More generally still, this instructional program could be combined with similar ones developed in other domains to form a staging ground to alert students to generic hazards of oversimplification and to prepare them to deal with complexity across domains. (Note that an aspect of the instructional approach that is considered crucial for transfer but that receives less attention here is the active involvement of the learner. The role of student participation and exploration becomes clearer in the detailed example presented later in the chapter.)

OVERVIEW

The chapter begins by posing a set of problems for cognitively based theories of learning and instruction. These problems revolve around concern for advanced knowledge acquisition (i.e., post-introductory learning) in a content area. At advanced stages of knowledge acquisition content becomes more complex and the relationships across the cases that knowledge has to be applied to become more irregular. We call domains that have these features of content complexity and irregularity of application contexts ill-structured domains. At the same time that greater ill-structuredness must be dealt with by advanced learners, the goals of learning shift: (a) from the attainment of superficial familiarity with concepts and facts to the mastery of important aspects of conceptual complexity, and (b) from knowledge reproduction to knowledge use (transfer, application). (See Feltovich et al., 1989; Spiro et al., 1988; Spiro et al., 1989, for detailed discussions of advanced knowledge acquisition.)

After presenting a brief discussion of problems in dealing with advanced knowledge acquisition in ill-structured domains, we present a remedy: the Cognitive Flexibility Theory of learning, knowledge representation, and knowledge transfer. By cognitive flexibility we mean the ability to spontaneously restructure one's knowledge, in many ways, in adaptive response to radically changing situational demands (both within and across knowledge application situations). This is a function of both the way knowledge is represented (e.g., along multiple rather than single conceptual dimensions) and the processes
that operate on those mental representations (e.g., processes of schema assembly rather than intact schema retrieval).

We then discuss the instructional approach systematically derived from that theory and implemented in computer learning environments, the Cognitive Flexibility Hypertext approach to random access instruction. Key features of the approach are illustrated by a functioning hypertext prototype that teaches aspects of the complex multithematic structure of the film "Citizen Kane" using random access videodisc. The generality of the approach is underscored by a brief presentation of highlights of Cognitive Flexibility Hypertext prototypes in other domains (e.g., cardiovascular medicine and military strategy).\(^1\)

We are especially concerned with how the knowledge representations that are built by using programs like KANE support the application of old knowledge in new situations. We stress the process of situation-dependent schema assembly as against the views of schema theories that depend on the mere retrieval of precompiled generic knowledge structures that are monolithically superimposed on the concrete case at hand. The latter approach is simply too unwieldy to support transfer when there is a lot of complexity in the individual case of application and when cases vary considerably, one to the next. If you may have to use knowledge in many ways, in a diverse set of circumstances, you cannot rely on a small number of rigidly prepackaged schemas (see Schank, 1982, as well).

A Note on Hypertext. The term hypertext refers to computer-based texts that are read in a nonlinear fashion and that are organized on multiple dimensions (see Marchionini, 1988, for a review). The same material (which can be any kind of randomly accessible medium, e.g., text, video, audio) is capable of being explored in different ways, with different exploration paths producing what are essentially multiple texts for the same topic. We discuss hypertext later—in particular how the features of our approach avoid problems commonly found in other hypertext systems, such as the problem of pre-stored links and the problem of getting lost in a labyrinth of connections between ideas. For now, however, it is worth pointing out that the outline of the chapter just presented also corresponds to a systematic response to widespread problems in the development of hypertext learning systems. In particular, work on hypertext has tended to be atheoretical, driven by the power of the technology rather than by a clear sense of how to respond to two key issues: (a) the stages of learning and purposes of learning for which this unfamiliar kind of instructional environment may be best suited—not all kinds of learning require so complex and potentially confusing an approach; and (b) the cognitive psychology of nonlinear learning—hypertext systems would be easier to use and would support greater educational attainment if they were systematically designed in accordance with a theory of how the information will be processed, mentally represented, and later used (see Spiro et al., 1988). This chapter can be thought of as being sequenced to correspond to these questions about hypertext (as well as forming a natural sequence for the presentation of problems of advanced learning and their solutions—as described in the overview).\(^2\)

Our answer to the questions that we said should be posed for any hypertext systems are that they are best suited for advanced learning, for transfer application learning goals requiring cognitive flexibility, in complex and ill-structured domains—rather than introductory learning, for memory tests, in simpler domains. (Incidentally, we were able to avoid the endemic atheoretical approaches to hypertext development only because of a fortunate coincidence of sorts: Our work on the cognitive psychology of learning for transfer in ill-structured domains happened to precede our interest in computer-supported instruction; Spiro, 1980; Spiro & Myers, 1984; Spiro et al., 1987.)

ADVANCED KNOWLEDGE ACQUISITION AND THE PROBLEMS OF ILL-STRUCTUREDNESS, COGNITIVE FLEXIBILITY, AND KNOWLEDGE TRANSFER

Two important things happen as you move beyond the initial introduction to a content area to more advanced stages of knowledge acquisition in that area: First, the conceptual content tends to become more complex and the basis of its application more ill-structured; and second, the goals of learning and the criteria by which learning is assessed shift (or should shift): (a) from superficial or introductory level familiarity with concepts to the mastery of important aspects of complexity (despite their difficulty); and (b) from accru-

\(^1\)The three hypertext systems are fully functioning prototypes. However, because they are currently used only for research, they contain a limited number of cases and commentaries. They are not fully developed curricula, although preparing them for that function would simply be a matter of adding more cases and commentaries—nothing in the computer programs themselves would change.

\(^2\)One further note may be helpful. The terms hypertext, hypermedia, and HyperCard are often confused. Hypertext has already been discussed. HyperCard is merely one kind of programming environment for hypertext development; it was not used for the Kane program. Hypermedia refers to nonlinear computer learning systems in any medium (including multiple media). In that sense, it is a more general term than hypertext. However, because only one of the nonlinear learning programs that have been based on Cognitive Flexibility Theory employs multiple media (the Citizen Kane program), we feel uncomfortable referring to the set of systems as hypermedia. Yet the set should have a common name, given that a common theoretical basis is shared. So we refer to all of the systems as hypertexts. This designation is consistent with the more general usage of the term text in post-structuralist literary theory to refer to any object of rich interpretation, including pictures. So, the instructional program using Citizen Kane is a nonlinear 'text' that relies heavily on film segments, as well as written text.
rate reproductive memory and imitative rule-following for instructed material to the ability to apply what was taught in new and greatly varying contexts—knowledge transfer.  

What do you have to do to attain a deep understanding of a complex concept, to “get it right”? What has to be done to be ready to apply conceptual knowledge in a domain where the phenomena occur in irregular patterns? How can one be prepared to use knowledge in the great variety of ways that may be required in a rich domain? Unfortunately, the indications are that what should be done in all of these cases is very often just the opposite of what tends to be done in conventional instruction practices (Spiro et al., 1987). Learning and instruction for mastery of complexity and application in a complex and ill-structured domain cannot be compartmentalized, linear, uniperspectival, neatly hierarchical, simply analogical, or rigidly prepackaged (Spiro et al., 1987; Spiro et al., 1988). Yet it much too often is, and the result is the development of widespread and serious misconceptions and difficulties in knowledge application (Feltovich et al., 1989; Spiro et al., 1988; Spiro et al., 1989). This is because complex and ill-structured knowledge domains are characterized by such features as nonuniformity of explanation across the range of phenomena to be covered, nonlinearity of explanation, nonadditivity following decomposition, context-dependency, irregularity of overlap patterns across cases (reducing the effectiveness of prototypes and simple analogies), absence of wide scope defining features for category application, and so on (see Spiro et al., 1987; Spiro et al., 1988, for discussions of domain ill-structuredness).

We have shown in a number of studies that the learning of complex content material in ill-structured domains requires multiple representations—multiple explanations, multiple analogies, multiple dimensions of analysis (see, e.g.,

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1An example of a transfer measure for Citizen Kane is comprehension of critical commentary on the film. It has been amply demonstrated that text comprehension requires the mobilization of an appropriate background knowledge scaffolding. This requisite background knowledge changes across the many texts written about the film. Ability to assemble comprehension-supporting background knowledge over a wide variety of texts (compared to comprehension scores of control subjects) would indicate the acquisition of one kind of flexible transfer ability.

A note on terminology is helpful before continuing. In this chapter we use the term concept very broadly. We sometimes call schemas concepts, and we frequently refer to the complex themes of Citizen Kane as concepts. Sometimes abstract perspectives are called concepts. No theoretical significance should be attached to this usage. It is merely a convenient way to make a very gross distinction between abstract, conceptual knowledge and information about concrete cases. Similarly for our use of the term case. We refer to the short scenes from Citizen Kane as mini-cases (sometimes, in more general theoretical discussions, as cases). Sometimes we call examples or events cases. We are simply lumping together as cases anything that is an actual happening or a description of an actual happening, whether it is a scene from a film, a medical case, or an historical event. This is part of the same fundamental distinction we draw between conceptual knowledge and cases (things that actually happen).

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7. Cognitive Flexibility and Hypertext

Spiro et al., 1987; also see White & Frederiksen, 1987). Mental representations need to be open rather than rigid and closed; nonlinear instructional sequences need to be followed to avoid missing key points; assumptions of regularity and homogeneity have to be replaced by acknowledgment of irregularity and heterogeneity. Learning that has these characteristics of openness and plurality produces cognitive flexibility: the ability to adaptively re-assemble diverse elements of knowledge to fit the particular needs of a given understanding or problem-solving situation. In an ill-structured domain, one cannot fit the wide variety of real-world cases of a given type that will be encountered to the same "plaster-cast" knowledge structure (although a common failing of advanced learners is that they will try very hard to do this).

Standard technologies (e.g., books, lectures, etc.) are not well suited to these requirements for the development of cognitive flexibility. But the problem goes beyond the limitations of traditional instructional technologies: theories of cognition and instruction too often focus either on introductory learning or advanced learning in well-structured domains. They therefore have features that are antithetical to those required to deal with the complexities that need to be mastered at advanced stages of knowledge acquisition, as described previously. (See Spiro & Plaepv, 1984; Spiro et al., 1987, for discussions of limitations of earlier versions of schema/frame/script theories. Cognitive Flexibility Theory is a response to those limitations.)

Actually, although there has been considerable research attention devoted to differences between experts and novices, the intermediate stage of advanced knowledge acquisition that bridges between novicehood and expertise remains little studied. This neglect has had serious consequences given the indications from our research that characteristics of early learning are immi
cial to advanced knowledge acquisition—many of the strategies of learning and instruction that are most successful in introductory learning (e.g., the use of analogy) form impediments to the eventual development of more sophisticated understandings (Feltovich et al., 1989; Spiro et al., 1988; Spiro et al., 1989). So, new theories are needed, as well as new technologies appropriate to those theories. In the next section we first discuss Cognitive Flexibility Theory and then the technological instructional orientation derived from that theory, the Cognitive Flexibility Hypertext approach.

LEARNING AND INSTRUCTION FOR COGNITIVE FLEXIBILITY: CRASS-CROSSING CONCEPTUAL LANDSCAPES

The central metaphor of Cognitive Flexibility Theory is the "criss-crossed landscape." The metaphor derives from Wittgenstein (1953) who, in his preface to the Philosophical Investigations, desired that all of his attempts to weld his complex ideas into a conventionally unified exposition, to force his
ideas in any single direction, crippled those ideas. Rather than reducing the complexity of his ideas for purposes of expositional elegance and (spurious) theoretical parsimony, he opted instead to write a different kind of book. He would treat the philosophical topics that were his subject as forming a complex landscape, and he would sketch those topics as sites within the landscape. He would then arrange these sketches of local regions of the landscape to form a kind of album. The sequences in the "album" would represent different traversals of the (conceptual) landscape. So in order to insure that the complex landscape would not be oversimplified, he would endeavor to "criss-cross" it in many directions; that is, the same sketches of specific issues (or cases) would reappear in different contexts, analyzed from different perspectives.

Although Wittgenstein did not explicitly make the following claim, it seems likely he would agree (and in any case we argue) that because the complexity of a single region (issue, example, case) in a landscape would not be fully graspable in any single context, its full multifacetedness would be brought out by rearranging the sequence of sketch presentations in the album so that the region would be revisited from a variety of vantage points, each perspective highlighting aspects of the region in a somewhat different way than the other perspectives. A synoptic view of the complexity of the conceptual landscape would cumulatively emerge over a number of traversals—the richness of the subject matter would not be crippled if the content was examined in many different ways.

Cognitive Flexibility Theory generalizes Wittgenstein's metaphor of the criss-crossed landscape to apply to any complex and ill-structured knowledge domain. Furthermore, the metaphor is extended beyond Wittgenstein's concern for exposition (i.e., a style of writing). We use the metaphor to form the basis of a general theory of learning, instruction, and knowledge representation. One learns by criss-crossing conceptual landscapes; instruction involves the provision of learning materials that channel multidimensional landscape explorations under the active initiative of the learner (as well as providing expert guidance and commentary to help the learner to derive maximum benefit from his or her explorations); and knowledge representations reflect the criss-crossing that occurred during learning.

By criss-crossing topical/conceptual landscapes, highly interconnected, web-like knowledge structures are built that permit greater flexibility in the ways that knowledge can potentially be assembled for use in comprehension or problem solving. The likelihood that a highly adaptive schema can be assembled to fit the particular requirements for understanding or acting in the situation at hand is increased. In other words, the range of differing situations that the knowledge could be transferred to is increased. In ill-structured knowledge domains, with their great heterogeneity across potential instances of knowledge application, this flexibility is essential. Because one cannot have a prepackaged knowledge structure for every situation that might be encountered, the emphasis must shift from intact schema retrieval to flexibility of situation-specific schema assembly (see Spiro et al., 1987; Spiro et al., 1988). By criss-crossing a conceptual landscape in many directions, knowledge that will have to be used in many ways is taught in many ways.

Random Access Instruction as the Ideal Medium for Criss-Crossing Ill-Structured Domains: New Kinds of Learning and Instruction for Cognitive Flexibility Made Possible by Computers

Clearly, Cognitive Flexibility Theory, with its emphasis on repeated presentations of the same material in rearranged instructional sequences and from different conceptual perspectives, is most efficiently implemented in delivery systems with random access capabilities (e.g., programable videodisc, as in the program discussed in this chapter). The "random access instruction" implementation of Cognitive Flexibility Theory acts as an antidote to the various forms of failure in advanced knowledge acquisition frequently associated with traditional learning and instruction (Coulson, Feltovich, & Spiro, 1989; Feltovich et al., 1989; Spiro et al., 1988). If typical approaches have overlinearized, one can construct nonlinear presentations. If material has been presented from just one point of view, one can re-present it from different points of view. Cases that have been slotted in a rigid hierarchical structure can be repeatedly re-presented to attain hierarchical or montage-like structural representations. If partially overlapping exemplars have been indiscriminately lumped under one category in a way that causes important differences among them to be missed, one can demonstrate the diversity amongst the similarity. Or, if exemplars that partially overlap in important ways have been separated into different conceptual categories, the similarity amongst the diversity can be demonstrated. If aspects of knowledge have been overly compartmentalized, their insularity can be overcome by joint presentation. If decomposed elements are not additively assembleable, they can be reassembled with a more complex combinatory logic. If an old example/case is employed in monolithically as a precedent for a new one, you can decompose examples and then recombine aspects of different examples to achieve the most accurate (the most closely fitting) set of multiple prece- dents for understanding in a new situation.

We call the computer-based instructional programs derived from Cognitive Flexibility Theory and built to carry out such operations as those just listed Cognitive Flexibility Hypertexts.

A Note on What Kind of Hypertext We Are Talking About. The Citizen Kane program and the other Cognitive Flexibility Hypertexts have a special-
ized function—they are concerned with structural characteristics of the cases they try to provide help in understanding. Rather than trying to provide a diverse and entertaining experience, they are trying to simulate experience, insofar as structural aspects of experience are relevant to the knowledge representations that must be developed to support cognitive processing of subsequently encountered cases. The presented material is only that which is needed to form a fairly full representation of a case's internal structure. We are not saying that other material, such as information about an author (or the director of Citizen Kane) would not be helpful as well. It is simply our intention to deal with one important and difficult aspect of the hypertext problem: Having the hypertext convey complex knowledge structural characteristics.

A Note on the Use of the Terms "Random" and "Flexible." Two potential misunderstandings should be mentioned. First, the designation random is not intended to denote an absence of systematic structure underlying the instructional approach. Far from it. There is an abundance of structure in Cognitive Flexibility Hypertexts, albeit a highly multidimensional and web-like structuration. The randomness concerns the computer system's ability to utilize the underlying structure in a great variety of ways and without inconvenient delays (as when you need to fast-forward videotape to get to a distant segment). The same information is easily accessed in various combinations with other, perhaps distant information in a large number of different contexts.

Second, by promoting cognitive flexibility we are not advocating an "anything goes" mentality. To say, for example, that a text may support multiple alternative interpretations is not to say that interpretations may be offered without warrant. Learners must always be encouraged to find evidence for their claims; A strength of our systems is that their structure and operation make the search for evidence more manageable.

Beyond Access: A Note on the Need for Grounding of Hypertext Development in a Theory of Learning and Instruction. We refer to the systems that we have built as hypertexts because of their nonlinear and multidimensional nature. (See Marchionini, 1988, for a review of hypertext work.) However, we wish to emphasize again (see the earlier "Note on Hypertext") our belief that the debate on the hypertext notion has been too narrowly concerned with issues such as data access and too little concerned with the theoretical character of much of the hypertext work (Spiro et al., 1988). We believe that it is vitally important that hypertext development not be divorced from underlying theories of cognition and instruction. We must know more about how people think and learn in the radically novel form required by hypertexts. We offer Cognitive Flexibility Theory and its extension to random access instruction as a grounding for hypertext approaches. Furthermore, we do not believe the additional cognitive load placed on learners by nonlinear instruction is always desirable. In more well-structured and simple knowledge domains, and, perhaps, in some introductory learning, the disadvantages of hypertext approaches may outweigh their advantages, and traditional approaches are likely to be more efficient and effective. We contend that hypertexts should be used primarily in those situations where traditional approaches would interfere with the goals of knowledge acquisition, namely, for advanced learners striving to master complexity and prepare for transfer in ill-structured knowledge domains.

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A COGNITIVE FLEXIBILITY HYPERTEXT FOR MULTITHEMATIC EXPLORATIONS OF CITIZEN KANE: AN EXAMPLE OF RANDOM ACCESS INSTRUCTION

The Cognitive Flexibility Hypertext, "Exploring Thematic Structure in Citizen Kane" (referred to by the shorthand designation KANE, which can also be read to stand for Knowledge Acquisition by Nonlinear Exploration), is a random access instruction approach to advanced understanding of a film that has a complex and subtle structure. Segments of the film, combined with text, are systematically re-presented at different times, in different content combinations, in different sequences. The result of these arrangements is multiple texts about the film, for different learning purposes, produced by automatic computer re-editing. The program has been designed for use by advanced high school students and college students. The intent of the program is to go beyond traditional instructional approaches that tend to be overly linear, one-dimensional in their abstractions, and, in general, reductive of the complexity found in literary works. In addition to the goal of fostering advanced understandings of this specific film, the more general intention is to demonstrate to students the complex nature of literary comprehension and to help students begin to build a more adequate repertoire of cognitive skills for the processing of complexity and for the application/transfer of complex knowledge to new situations. The work on KANE is part of a larger research program whose goal, currently being explored in several domains, is to discover general principles of effective advanced learning and instruction for complex subject matter. (In addition to their intended use in advanced knowledge acquisition, the hypertext programs can also function as helpful research tools for expert specialists, and of course, in experimental studies of nonlinear cognition and instruction).

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The program was conceived by the first author, who also conducted the content analysis of the film. The second author wrote the program code from the specifications provided to him. Michael Jacobson helped with some of the user-interface design.
At this time, the Kane program does not try to teach all aspects of the film. Rather, our more restricted current focus is a case-based understanding of the internal "semantic" structure of the film, particularly as it bears on the Kane character (i.e., his motivations, values, beliefs, and so on). (Obviously, if we wanted to be more ambitious and teach the entire film, rather than just the complex makeup of its main character, the film's convoluted narrative style and many technical innovations would be ideally suited to the random access approach.) Also, at this time the program uses a preestablished underlying structure, albeit a highly complex, pluralistic, and flexible one. Upcoming versions will incorporate more options for users to generate their own structural schemes in addition to those provided for them. However, the current version does allow users considerable leeway in the secondary structures that they may add to the provided underlying structure; and freedom of student-initiated exploration of the landscape as it is complexly mapped by the provided structure is a key feature of the program (as its title indicates). As is illustrated later, the provided underlying structure retains the potential for quite considerable openness in the interpretation of the work (Barthes, 1967).

"Exploring Thematic Structure in Citizen Kane":
A Brief Description of the Operation of the Program

The following is a brief description of the program intended to provide just enough familiarity with its operation to form a context for the discussion of the theoretical implications of the program's features that comes after this context-setting section. It is important to remember that the main intent of this chapter is to present our theoretical perspective and the systematic approach to computer-supported instruction that follows from the theory; discussion of the Kane program per se is not the purpose of this chapter. Accordingly, the reader interested in more information about Kane is directed to a more detailed, archival description of the program that will appear elsewhere.

Before going any further, however, an important disclaimer should be noted: Given the limitations of space, the accumulation of a critical mass of highly interconnected knowledge by a large number of "landscape crossings" cannot be fully illustrated here. The examples that are discussed


It is worth noting again that the Cognitive Flexibility Hypertext approach is a general one—the same principles lead to very similar hypertexts in radically different knowledge domains. The issue of domain-independence is relevant here. We believe that there are considerable differences across domains, but the principles of domain exploration are the same (just as New England and Southwestern landscapes differ, whereas general principles of how to explore a landscape can be applied to both). For example, in any landscape or complex knowledge domain, multiple traversals will be important.

7. Cognitive Flexibility and Hypertext can give only the faintest hint of the experiences provided by more extended exposure.

Preliminaries. It should be kept in mind that Kane is an advanced knowledge acquisition environment, not a tool for introductory learning. Thus, in the initial phase of working with the program, it is expected that students (college or advanced high school) will have already watched the film in its natural sequence at least once and preferably two or more times to become very familiar with it, and that they will have been thoroughly introduced to the major themes—before you can "play" with content, examining it in a variety of new and interesting ways, the content to be played with must be well learned.

Thematic Organization: Multiple Wide-Scope "Schemas of the Whole." For the main instructional part of the program, an extensive and detailed thematic analysis was carried out of Side 2 of the Citizen Kane videodisc, containing several scenes and lasting approximately 30 minutes. The analysis was based on 10 themes chosen for their prominence in the critical literature on the film. The themes have wide scope. Each theme has been put forward by some experts as being capable of providing a complete account of the Kane character's behavior, motivations, failings, and so on. In a sense, each of these complex and powerful themes has been thought of by some subset of expert analysts as providing a complete schema for understanding Kane. Examples of themes include: "Hollow Man" (Kane's inherent soullessness), "Wealth Corrupts," and "Outsized Ambition." Additionally, two of the themes involve Kane's relationships to important symbolic characters in the film, Leland and Thatcher. The course of Kane's development can be conceptualized as a dynamic movement toward and away from a complex of features crystallized in those characters (roughly: populism, friendship, and principled behavior for Leland, and wealth and emotional detachment for Thatcher). As is seen later, the use of several comprehensive themes makes it more likely that an appropriate one (or subset combination) will be available to be adaptively fit to the particular needs of situations encountered in the future. Furthermore, the variability of usage of each theme is stressed in instruction (see the discussion of variability in concept application). So, knowledge transfer is facilitated by having a large number of wide-scope interpretive schemas available and by enabling learners to use each of those schemas in a flexible manner. The use of multiple organizing perspectives/schemas in the instructional program is an illustration of one of the most important recommendations of Cognitive Flexibility Theory: Use multiple representations for advanced knowledge acquisition in ill-structured domains.

The choice of themes does not involve an especially delicate selection
process. In an ill-structured domain, more schemas are better than less; so each time you add another credible schema you are adding to the scope of coverage. (Again, each of the themes could be treated as a full schema. The themes are also called concepts at times. See footnote 4 for a discussion of the terminology used in this chapter.) Therefore, there is no need to adjudicate between alternative wide-scope schemas offered by different experts, discarding some because they are not as "good" as others. In an ill-structured domain any widely supported candidate schema is likely to be useful on many occasions and less relevant on others—they are all "correct," but only to a limited extent. The more of them you have, the more likely you will be to have an available subset that is especially useful for the needs of processing some new case (keeping in mind that in ill-structured domains there is considerable variability across cases and each case is individually complex). By the time you get up to 10 or so wide-scope schemas, a lot of territory has been covered (certainly much more than with just one schema). So, given the need for an expansive theme selection policy (the theory requires that as many credible perspectives as possible be incorporated up to limits of cognitive tracking capacity, to support future knowledge transfer), there is little pressure to choose between competing themes for inclusion in the instructional program. In any case, any theme list will be insufficient by itself given the necessity of knowledge assembly in the context of new cases in ill-structured domains (i.e., new knowledge structures will typically have to be built for a new case by combining themes).

It should also be noted that it is all right for the themes to overlap somewhat (it would be difficult to find any set of themes that are mutually independent, yet still have wide scope of application). However, the themes in Kane only partially overlap. Each makes some novel contribution not made by the others. (Obviously, it would be undesirable to use a set made up of very similar themes, themes that are not much more than paraphrases of each other.)

Case Organization: Division into Mini-Case Scenes. The second side of the videodisc was divided into 25 natural units. As is seen later, the precise subdivision chosen is not particularly significant so long as it is a defensibly reasonable one, because any of a number of possible subdivisions produce roughly equivalent effects—the important thing is that the chosen segments provide a rich staging ground for instruction. These scenes function as mini cases: Self-contained units that are short enough to permit rapid study (they mainly range from 30 to 90 seconds), but rich enough to allow for the complex interplay of multiple themes. Each of these scene "units" is coded with a vector that specifies which of the eight themes and two symbolic perspectives has a relevant role in a given scene; this information is the basis for the computer program's theme-based search (see later).

7. Cognitive Flexibility and Hypertext

An example of a mini-case scene, which is referred to in later sections of this chapter, is the following segment of the film (that takes less than 1 minute to view):

In this scene, Kane has just recently taken over the newspaper "The New Enquirer." The first edition of the newspaper since he took control of it will come out in the morning. Kane, his associates, and the newspaper staff have worked all night remaking the paper. Dawn is breaking. Kane's two exhausted associates are remarking on what a long day it has been. "A wasted day," says Kane. He complains that all they did was alter the surface of the paper. He wants to do something that is not superficial. He wants to make the Enquirer "as important to New York as the gas in this light." He then blows out the flame on the light, and the scene ends.

This is a very short scene, but it can teach many important lessons (and the number of lessons it can teach increases when the scene is contrasted with other scenes to draw additional lessons beyond those of the scene in isolation). Some of the lessons taught in the context of this 45-second scene are illustrated by the following optional theme commentaries drawn from the program (with theme and subtheme information included in brackets):

It's been a long day and night, but there is a weary sense of accomplishment in the group. Kane, however, considers it a "wasted day." He has completely remade "The Enquirer," from top to bottom, but that is not enough for him. The changes are too superficial. He wants his newspaper to become of central importance to New York. He wants the people of the city to depend on the "Enquirer" as much as they depend on the gas for their lights. [An illustration of the Outsized Ambition theme, and its Grandeur/Sweep and Egomania subthemes.]

By getting the people of New York to consider his newspaper to be as vital to them as "the gas in this lamp," he wants them to depend on him (through his newspaper, which Kane always treated as an extension of himself). [An illustration of the Power theme ("Control Others by their Dependence on You" subtheme).]

His reference to the gas in his lamp as typifying something that is essential to the city is ironic. Soon the gas lamp will be obsolete (as will Kane). This is one of the many instances of conspicuous misjudgment on Kane's part (as when he guarantees in 1938 that there will be no war in Europe). He underestimates the forces of change and consequently is a frequent misreader of the future (whether it is about gas as a source of power or newspapers as the dominant media for influencing people). He is constantly shown to be fallible, a trait that undermines his egomanically pitched ambition. [An illustration of the Fallibility/Morality subtheme of the Outsized Ambition theme.]

Everyone has worked all day and all night, but Kane is the only one who is still going. This is typical of the energy and enthusiasm of his early years. (His
youthful energy contrasts starkly with the deathlike torpor and stagnancy of Kane when he is older.) [A negative example of the Hollow Man theme illustrating the Lifelessness subtheme. His energy and vitality in this scene are opposed to his later lifelessness and lack of inner spark.]

A lot of the complexity of the domain has begun to be illustrated from just one mini-case lasting less than 1 minute. As we see later, there are several purposes served by this design strategy of structuring in small segments (e.g., acceleration of experience acquisition, making complexity tractable for the learner, facilitation of subsequent restructuring of knowledge, and others).

An important note that will help to avoid confusion in the exposition throughout the remainder of the chapter is that instances from the film are treated as "cases" from Kane's life. So, when our theoretical discussions refer generally to the role of cases, that means larger scenes from the film, while mini-cases correspond to very short scenes from the film. Again, scenes and mini-cases are used as interchangeable terms in this chapter.

**Contextual Support, Thematic Commentary and Guidance.** After a scene has been viewed the frame is frozen and several options are presented. Because the scenes are studied out of sequence, the user always has an option to request "stage-setters," information about the context in which the scene is occurring, what has just happened before the scene, and so on. Thus, the "out-of-the-blue" effect of nonsequential presentations is lessened. (It should be remembered, however, that the film has already been viewed in its natural sequence prior to this advanced stage of learning.) Also, of course, it is possible to use the program to watch clusters of scenes sequentially; that is, the student can study cases with a larger "grain size" than the mini cases. This is recommended only for later stages of using the program, in order to avoid the confusion likely to result from starting right in with a complex thematic analysis of too large an amount of case information. (See the later section on "experience consolidation" for a discussion of the cognitive advantages of introducing complexity in "bite-size chunks").

Each scene is presented with a text overlay in a corner of the screen listing the themes the scene contains. The themes that were targeted in the menu selection (see the section immediately following) are presented at the top of the list in a different color than the themes present in that unit but not targeted for search by the student. The student can choose to see text commentary on the particular nature of any theme's instantiation in that scene. Two important kinds of information included in the commentaries concern **accessibility** (why the particulars of that scene constitute grounds for saying that the given theme is illustrated there—how the generic theme is tailored to apply to that particular context) and **across-scene relations** (how a particular instantiation of a theme relates to instantiations elsewhere in the film).

Finally, the student can choose to see the scene over again, exit back to the menu, or continue with the next scene in the stack. Also, the student can examine a "road-map" of his or her prior explorations.

In summary, instruction on complex subject matter must be made as tractable for the student as possible. We have found in our research that ignoring complexity leads to unacceptable learning outcomes (Coulson et al., 1989; Feltoeich et al., 1989; Spiro et al., 1989). Essential content complexity and application irregularities must be faced, even if they are difficult to learn and teach. However, every effort must be made to help the student to manage that important complexity.

**Theme-Based Exploration: Re-Editing the Film as Function of Thematic Content.** Students operating in the program's **self-directed** mode (there is also a **sequential** and an **experimentor-controlled** mode of operation) are presented with a menu of themes and instructions for combining themes. They can choose to examine the occurrences of a single theme (which may be specified as to whether it is a positive or negative instance of a theme, if desired—for example, some event related to poverty would be a negative instance of the wealth theme). Or they can choose to search for those scenes that illustrate combinations of several themes (conjunctively or disjunctively). The menu selection leads to a search for minicasces/scenes whose vectors have the targeted thematic properties. For example, the student may choose to look for scenes that illustrate both the Wealth Corrupts and Hollow Man themes. Those scenes that fit the request are then put in a stack of scenes that the student can view.

In other words, in a very short amount of time, a re-edited version of the film that highlights just the theme(s) that the student wants to explore is ready to be presented. Because of the large number of scenes and themes, there are literally thousands of potential re-editions, each of which has some instructional significance (some, obviously, having more significance than others). This plentitude of re-editions relates to one of the important lessons of ill-structured domains: Because of domain irregularities and novelty resulting from the exponential explosion of the multiple factors in a complex concept, you always gain from additional experience—for example, a physician can never have "enough" experience.

**Non-Preprogrammed Special Initiatives: User-Construction of Interpretive Essays.** Adding to the flexibility of the program is a miniature author-
We then more briefly highlight several other important design features of Cognitive Flexibility Hypertexts, with particular reference to their instantiation in KANE. The discussion again focuses on those features of learning and instruction that are affected by characteristics of complexity and ill-structuredness, as those characteristics relate to the attainment of the goals of advanced knowledge acquisition (mastery of complexity and knowledge transferability/applicability). In other words, wherever possible, the rhetorical form for these discussions follows the basic frame that was originally used to move from Cognitive Flexibility Theory to the instructional implementation of the theory’s implications for application:

Because ill-structured domains have property X, the structural and processing requirements for attaining transfer are therefore Y. So, to get a learner to have the skills and knowledge to be able to achieve transfer, instructional systems ought to have design feature Z.

A sample instantiation of this frame would be:

Because concepts in ill-structured domains have the property of substantial variability across their case applications, the structural and processing requirements for attaining transfer are therefore to understand the nature and scope of that variability, as well as the way that concepts get tailored to cases and cases signal the need for accessing concepts. So, to get a learner to have the skills and knowledge to be able to achieve transfer, an instructional system ought to have the following design feature (among others to address this need): The system should allow the student to sequentially study just those parts of cases that contain examples of uses of the concept; that is, teach conceptual variability by demonstrating it in one place (accompanied by appropriate commentary on the nature of the conceptual variability).

The Mini-Case as the Fundamental Unit of Instruction:
Structuring in Small Segments for Tractably
Accelerated Acquisition of Case Experience
and the Development of Flexibly Assemblable Knowledge

The mini-case (a segment drawn from a larger case) is the starting point for all instruction in Cognitive Flexibility Hypertexts. The rationale for this design decision is discussed in detail in this section.

It should be noted that KANE also allows well-structured aspects to be taught (e.g., besides showing how themes differ across instantiations) the program teaches what distinguishes each theme (i.e., what theme instantiations have in common). However, given limitations of space, we emphasize the more novel treatment of complexity and ill-structuredness.
Case-Based Exploration: The Central Importance of Actual Occurrences in Ill-Structured Domains. In an ill-structured domain, across-case variability is, by definition, too great to allow abstract conceptual knowledge to have a dominant role. By the definition of ill-structuredness, any abstraction or generalization will inadequately account for what happens across the range of cases that the knowledge will have to be applied to. Thus, in any ill-structured domain a more case-centered approach is needed.

Cases Cause Problems, Too: The Rationale for the Mini-Case. However, even the individual case is too complex and unwieldy a unit. Each case means too many things to be useful when treated as a monolithic unit. For example, isolated parts of a case may have instructional value but go unnoticed because they appear to lack significance within the frame of reference of the case as a whole. More seriously, intact cases used in instruction are frequently the cause of a problem in subsequent knowledge application: the tendency to map a new case completely to a single well-learned prototype, when part of the old case is misleadingly related to the new one—in ill-structured domains multiple representations are the rule, and that includes understanding a new case by reference to multiple prototypes. When cases are taught monolithically, their representations are harder to pull apart in the way that is necessary for transfer-enabling flexible reorganization of knowledge. Thus, in an ill-structured domain, an intermediate course must be followed: Just as one must not rely too much on abstract knowledge when dealing with a new case, one also can not rely too much on intact case-based reasoning, when the latter is taken to mean reasoning to a new case from a single precedent case.

Accordingly, as we have already mentioned, Cognitive Flexibility Hypertexts use segments drawn from cases—mini-cases—as the focus of instructional organization. KANE uses very short pieces of larger scenes as the mini-cases. Each mini-case receives interpretations across all of the multiple thematic dimensions that are relevant to it. (It is important to note that the entire case is always reconstructible in the hypertexts, and at some point during instruction the student should combine the mini-cases that belong to a larger case, so that they can learn how mini-cases configure to make up an intact case. The programs make it very easy to do this.)

It is worth calling special attention to a serious potential misinterpretation of what we mean by a mini-case. Mini-cases are not cases decomposed into their constituent features—they are not “abstract slices” of a case (e.g., the parts of a medical case that relate to vascular impedance). Such an approach would be antithetical to Cognitive Flexibility Theory because it would convey the mistaken notion, which is eagerly accepted by students, that the features of cases are independent, that one can study the aspects separately and then additively reassemble the whole case from those separately considered conceptual parts. Rather, mini-cases are chronological segments of a case (e.g., the first 3 hours of a battle, or frames 254–416 in a film). Thus, they retain some of the complex multiplicity found in the case as a whole. In a sense, they are microcosms, cases in miniature rather than separate case “compartments.”

Advantages of Mini-Cases. There are several advantages to using mini-cases as the primary instructional organizing unit. We discuss them in turn in order to show how design decisions in our hypertexts are bolstered by converging theoretical considerations:

1. Experience-consolidation and the mini-case: Accelerated acquisition of experience by compacting and elaborating cases. In an ill-structured domain you need to see lots of cases—the more case experience you have, the better your performance will be (especially independent transfer performance). For example, that’s why experience is so valued in the professions (such as medicine); professional domains are notoriously complex and ill-structured, and professional training can not possibly provide sufficient experience in the limited amount of time available. Even with “problem-based” curricula, only a small number of cases actually get covered (which is very helpful for teaching the processes of intact case analysis, but less helpful for providing the multidimensionally analyzed, criss-crossed knowledge structures that need to be derived from case experience).

By breaking full cases into several mini-cases, and then conducting a rich analysis of each mini-case (i.e., compacting and elaborating case experience), and by focusing mainly on knowledge structural characteristics of each case, many more case experiences are provided, in an instructionally reasonable amount of time. The process of acquiring the case is consolidated. Again, better performance in ill-structured domains requires more cases and more case-processing experience.

It might be argued that the advantage of covering much larger numbers of cases by using mini-cases is lessened by the quality of the coverage. In fact, the learning made possible by our richly analyzed mini-cases is quite strong. Consider all of the lessons taught in the context of just the one 45-second scene and few minutes of processing of commentary described earlier (the “gas in the lamp” scene). In that scene, it was clearly shown how four themes were simultaneously relevant, important lessons about the general nature of each of those themes were taught, illustrations of how the general themes had to be tailored to that particular scene (case of application) were presented, connections were drawn between that use of the themes and others in the film, and so on. All in less than 5 minutes, and all in the context of a real application of the conceptual/thematic knowledge that is being taught (not an artificial, contrived textbook example tailored to teaching the concepts but not representative of the types of cases that the concepts will eventually
have to be used to understand—here, real scenes from the film). Now imagine what would happen if the in-depth understanding derived from that one mini-case presentation were to be compounded by similar rich lessons for 10 other mini-cases, with each one related to the others. And that would take approximately 1 hour. The effects of dozens of these experiences over several days is obviously quite potent.

Again, however, it is worth pointing out that we do not claim that learning with our mini-cases substitutes for actual case experience. Rather, we contend that one important thing that comes from case experience can be more effectively conveyed by covering compacted and elaborated mini-cases in the way that we do: namely, the criss-crossed, multidimensional representation of the structure of case-based knowledge. Furthermore, these structural characteristics are taught more efficiently in our systems than in real-world case experience for a number of different reasons: conceptual structure is highlighted for the case, rather than having to be inferred; optional expert guidance is available; one is not dependent on serendipitous occurrences of instructionally useful cases in fortuitous sequences; etc. To get a lot of useful case experience, you don't have to actually physically experience the case. Again, if the fullness of the case's structural characteristics is successfully extracted, the effects may be better than actually "being there", because of the larger number of cases that can be covered, because of sequencing for instructional impact, and so on.

Summarizing, an important function of Cognitive Flexibility Hypertexts is that they consolidate the process of experience acquisition. By using mini-cases, the student sees many more examples of rich case analysis (e.g., of how concepts interact in a single case), in a much shorter amount of time. Each mini-case scene in KANE is a case-based demonstration of the processes of complex thematic analysis. Furthermore, each scene provides a rich lesson in the complex thematic structure of the film. And it deals with the conceptual information in the way that it is needed in ill-structured domains: namely, concepts are embedded in "practice"—the treatment of concepts is tied to the cases they are being applied to (and remember, in an ill-structured domain concept application is far more variable across instances, and thus more difficult, than in well-structured domains).

2. The mini-case and the problem of early introductions of complexity: Making complexity cognitively tractable for the learner. The use of mini-cases not only allows more cases to be covered, it also has beneficial effects on the cognitive manageability of the complex case instruction required in ill-structured domains. We have referred to our research findings that indicate difficulties with the traditional instructional approach of incrementally additions of complexity (i.e., "start simple and then get more complex"). The early simplifi-

3. Avoidance of maladaptive over-reliance on prototype cases. One thing that makes a domain ill-structured is that the processing of some new case is unlikely to benefit from a direct mapping (of structure or content) to any single prior case serving as a prototype. The individual case is complex, and there is considerable variability across cases. This is not to say that there is nothing to be learned from earlier cases. Far from it. Cognitive Flexibility Theory is case-centered (rather than knowledge-centered), and cases are not just important to learn from: They also have a crucial role as precedents in the processing of new cases. But there is likely to be more than one antecedent case that will be useful for processing a new case. The Cuban Missile Crisis, as it was developing, was partly like the Appeasement of Munich, but partly unlike it, partly like Korea and partly unlike it, and so on (despite the fact that the policy arguments on President Kennedy's crisis team tended to
revolve around which of the similar antecedents should be the precedent used in forming strategy for the United States' response. By using mini-cases, the monolithic integrity of the intact case is undermined, with the result that the tendency to over rely on an exact mapping to just one precedent case is considerably lessened. Correspondingly, the need of mapping to multiple precedent/prototype sets, drawing on those parts of prior cases that are relevant is made clear, and the ability to appropriately assemble pieces of several precedent cases is enhanced.

4. Principled fragmentation for adaptive flexibility: The importance of mobile, recombinable knowledge elements. A key feature of ill-structured domains is that a single prepackaged schema or prototype case will typically be inadequate as background knowledge to support the processing of a new case. Thus, intact schema retrieval (or prototype retrieval) as a knowledge-based processing mechanism must be replaced by situation-specific schema- and precedent-case assembly. In a complex and ill-structured domain, small bits of information (either about prior cases or about abstract concepts) recombine in a large number of ways in the new cases that prior knowledge must be applied to. The use of mini-cases allows for easier situation-dependent knowledge assembly, because the cognitive processes of knowledge compilation are much easier to execute if they are operating on, say six mini-cases rather than six full cases.

More importantly, however, availability of a large number of mini-cases permits a greater range of potential precedent-case assemblies for use in understanding new situations. Paradoxically, decomposition into very small discrete units enables a wider range of nondiscrete representations (similar to the paradoxical effect of breaking things into many very small units to approach a continuum in integral calculus). By using very small units that are then recombinated with several others, it is much more likely that you will be able to assemble a precedent set to fit the many kinds of new situations that will be encountered in an ill-structured domain (a process facilitated by the mental record of and experience with recombinations derived from past "criss-crossings"). A domain must be substantially deconstructed in order to have a wide range of possible reconstructions. Think of the way the use of small dots in comic strips allows more flexibility for developing different kinds of shadings than do bigger dots. In an ill-structured domain, cognitive flexibility to adapt to case variability requires a rich variety of potential shadings of the knowledge that is to be assembled. By structuring with small case segments you will be able to better match knowledge representations to the complexity of the world.

5. Retaining openness of interpretation. Meaning in ill-structured domains is multivalent. The goal must always be to resist the premature "closing down" of the interpretive process as soon as one account is identified. This is especially true in literary domains where the typical literary work will support many interpretations. Structuring over small segments (i.e., using mini-cases) helps to retain openness and plurality. Analyses based on large units will tend to stress elements found across the whole unit, and thereby miss elements that have more local occurrence; this will be true to a greater extent for domains that have complex cases (as in literary domains). Similarly, the larger the unit of analysis, the more that interpretation will tend to narrow to some "common denominator" that fits all the constituents, again missing the more irregularly occurring local complexities. Because cases tend not to be homogeneous in an ill-structured domain, representing at the mini-case level helps to avoid these reductive biases and thus offers greater opportunities for representational fidelity to a heterogeneous reality.

Barthes has made similar arguments. In his analyses of literary works (e.g., 1967), he made the short segment, which he called a lexis (ranging in length from parts of a sentence to several sentences) the organizing unit for his analyses. He argued persuasively that this would result in an "open" and "plural" text, whereas if the text were structured over larger segments, it would be more likely to become closed to alternative interpretations. This is because many of the bases for opening up interpretation would be found only in parts of the text, but would be lost when the "grain size" is the text as a whole. As a result, the text would tend to have a more singular interpretation, uniformly applied throughout (again, because much of the basis for realizing that the text has to be seen in multiple ways would have been narrowed away).

The avoidance of closed and narrow representations by structuring in small case segments is particularly important for adaptive flexibility in schema assembly, which requires rich diversity in the way cases are represented. It narrowing occurs in case representations, then you will have fewer "shadings" available to you to optimize the fit of prior knowledge to new cases.

6. Power and efficiency of the program. Besides the cognitive and instructional advantages already discussed, the use of the mini-case also has several "logistical" benefits for the development and operation of the computer hypertext program. For one thing, by having a larger numbers of mini-cases, each coded with a 10-slot vector with three possible values in each slot, the number of case contrasts and traversal routes for "landscaping criss-crossing" that can automatically be generated by the program (without pre-programming of instructional sequences or pre-storing links across mini-cases) grows exponentially.

A time-saving advantage in hypertext development is that fewer cases have to be produced when each case results in several mini-case units. As we have already seen, quite a bit of instructional mileage can be gotten out of even a few cases if they are segmented into many complexly analyzed mini-cases. Of course, the efficiency of the program is further increased by the
fact that Cognitive Flexibility Theory requires that each mini-case be used more than once (i.e., the same landscape site, or scene in this case, is revisited on different traversals of the landscape).

Also, by using mini-cases it is much easier to effect a connection between a small part of one case and a small part of another case to which the former case is instructively related. It is more difficult to accomplish this when monolithic case blocks are used as organizing units.

7. Mini-cases help to avoid two common problems of hypertext: a confusing labyrinth of connections and the need to pre-store links. These technical issues in hypertext methodology are addressed at the end of this chapter.

We have devoted considerable space to the motivation for just one design choice in Cognitive Flexibility Hypertexts: the use of mini-cases (short scenes in KANE) as the primary organizing unit of instruction. In the sections that follow we talk about other design decisions; although these are also considered to be crucial, we do not illustrate their rationale and benefits as exhaustively.

Multiple Knowledge Representations and Theme Selection to Maximize Transfer

In an ill-structured domain no single schema will provide sufficiently complete coverage, which will account for sufficient variability in the way things happen in the domain. With the more limited view that results from a single representational system, the learner is not prepared to apply his or her knowledge to those new situations that are less relevant to that representation—and in an ill-structured domain there will be many such situations by definition. Or, in the less extreme situation where multiple schemata are provided, it usually happens (either through instructional influences or because of learner biases) that one or two of the schemata assume precedence over the others. Although this is not as serious a problem as that when only one schema is provided, it is nevertheless the case that in an ill-structured domain any reduction in the operative perspectives for analyzing the wide variety of cases encountered will be disadvantageous. To make up for the inadequacies of any single representational perspective, additional perspectives must be added. With a sufficient number of perspectives, a fuller, more "three-dimensional" view of the domain is achieved. By providing 10 equal, frequently applicable themes in KANE, we are making it clear to the student that any one theme permits only a limited view of the landscape. The student learns that the abstract conceptual world for the ill-structured domain is complex and not easily simplified.

So, advanced cognition in complex and ill-structured domains requires multiple knowledge representations. As we have already indicated, each of the 10 themes used in the KANE program is more than a mere descriptive attribute—each is a schema in itself. Each could be argued to provide the best full account of the KANE character. Rather than trying to show which is best, the program illustrates how they are all correct, and how their joint consideration produces the most adequate account. You cannot impose one interpretive scheme on the film; any scene mixes and blends several interpretive schemes. This lesson is amply taught in KANE, as each mini-case (scene) is viewed from several thematic and symbolic perspectives. By helping the student to fully cover each case/scene by pluralistically representing it, transfer is fostered in several ways: (a) the student learns how to fully interpret cases, facilitating the full interpretation of new cases encountered later; (b) the multiple coding of cases provides a larger number of access routes for their later retrieval from memory as background knowledge precedents for understanding new cases; (c) the interaction of conceptual perspectives is taught by their simultaneous consideration within a single mini-case context; and (d) having 10 wide-scope themes will "cover the landscape"—it gives you more flexibility in tailoring for schema assembly. Also, having 10 themes helps students to avoid the reductive bias of a "uniformity of explanation" (Coulson et al., 1989; Feltovich et al., 1989): with many equal themes none can dominate the others, and therefore all of these (now more minor) perspectives can be readily available to make their contribution as benefits to some new case.

Re-Reading and Rearrangement: Repetition Without Replication

The KANE program, like the other Cognitive Flexibility Hypertexts, relies heavily on the repetition of case information. However, this use of repetition is completely opposed to the typical purpose and consequences of repeating information in learning and instruction. Conventional uses of repetition in instruction are intended to strengthen the learning of some aspect of knowledge, with successive presentations each intended to mean the same thing each time. In contrast, our use of repetition is non-replicative. The aim is to illustrate the complexity of case information. Following the metaphor of the criss-cross landscape, the same content is presented in different contexts. This helps to keep interpretation from rigidifying toward an overly narrow subset of the lessons that the content should be teaching (and that the learner must be prepared to utilize in transfer situations). That is, the repeated presentations aim to point out for students how the same case information can take on importantly different shades of meaning at different times and how each case has many facets, some of which will tend not to be noticed in any single
context of occurrence. In complex and ill-structured domains, each unit of content is multifaceted. Each presentation of that content in a different context highlights another aspect of that multifacetedness, as well as illustrating context dependencies. There is a limit to the number of lessons that can be learned in any single presentation of content material, in any single context of presentation. Furthermore, by presenting the same case information at different times, in the context of various other cases, and with different conceptual elements stressed, a web of case and context interrelationships of the kind necessary for flexible knowledge assembly and transfer in ill-structured domains is established.

**Relationship to Poststructuralism in Literary Theory and Philosophy.** A similar role for re-reading in order to avoid reducing complexity was a central feature of Barthes' (1967) analysis of Balzac's short novel, "Sarassine," in S/Z. In fact, our general approach has many affinities to poststructuralist literary theories (like that of Barthes in the late 1960s), which also stress such factors as multiple codes, the importance of knowledge fragments, and the nonunifiability of rich cases by any single unifying logic. Not coincidentally, Wittgenstein's later work, which strongly influenced our thinking, has also been adopted by many poststructuralists. (Interestingly, Wittgenstein had originally intended to have an elaborate set of cross-references placed below each sketch in the *Philosophical Investigations* to enable cross-cutting the landscape of sketches in various directions with frequent re-readings in new contexts.)

**Theme-Based Exploration: Teaching Conceptual Complexity and Variability in Conceptual Application**

One of the main features built into KANE is the ability to have the program search for occurrences of any chosen theme and then re-edit the film to show just those scenes found in the search (along with accompanying commentary, stage-setting information, etc.). Theme-based explorations of the film are intended to teach both the complexity of the themes and the nature of their variability of instantiation in actual scene contexts. An important feature of abstract concepts in ill-structured domains is their irregularity of application (see also Barsalou, 1987). That is, each concept is used in a lot of different ways. Also, the same concept will apply to a variety of kinds of cases. These features have the consequence of making it hard to: (a) go from cases to concepts (problems of knowing which concepts are relevant from the case information), and (b) go from concepts to cases (problems of tailoring the way a concept is used to a particular context of its application). (Once again, in this chapter we use the term *concept* very broadly to make a gross distinction between abstract knowledge and case information. With this loose criterion, a complex theme in KANE can be referred to as a concept.)

**Theme-Based Search and Variability of Instantiation.** In general, the concepts of an ill-structured domain cannot be transmitted to learners the way they are in well-structured domains, namely by some direct process of providing general principles or definitions (perhaps with one or two examples as illustrations of the general principles). Instead, knowledge of concepts comes from having their uses (instantiations) demonstrated, rather than the concept being specified in the abstract. In an ill-structured domain the meaning of concepts is implicit, at least partly, in the pattern of their use of the concept (Wittgenstein, 1953). The theme-search feature of KANE (and a similar feature in the other Cognitive Flexibility Hypertexts) does what must be done in an ill-structured domain: It allows the nature of concepts to be shown (by a guided presentation of their actual occurrences), not told. The nature of the variability of theme-instantiation in KANE is conveyed in part by sequentially viewing an entire series of scenes that are instances of the theme. For example, the user can ask to view a series of brief scenes that all illustrate the Hollow Man theme. Thus, the program shows the variability in conceptual use—you *see* a set of different cases that are said to be instances of the concept. (Of course, you also see what is in common across the uses—but this is much easier to teach.)

**Commentary and Expert Guidance: Tailoring, Integrating, and Preparing for Access.** The thematic commentary that accompanies scenes also helps to convey conceptual complexity. Commentaries provide several kinds of assistance. First, they explain how the scene instantiates the theme; that is, they *tailor* the theme to the case. Second, they discuss features of the scene that lead one to consider it to be an instance of the theme, information that helps students learn the difficult process of accessing concepts from case information. Third, the commentaries help with two kinds of integration functions: They relate the theme to other themes in the same scene (building theme connections and reminding learners about the importance of the *simultaneous* use of multiple perspectives); and they relate the current instance of the theme to other instances of the theme elsewhere in the film.

Also helpful in the management of conceptual complexity is the use of more differentiated subtheme designations that tell what type of instantiation of the theme is being observed. That is, each theme is analyzed into various "senses," and the instantiated sense is presented in the header for the commentary. For example, a subtheme of the Power theme is "Kane controls others by having them depend on him." The subtheme information also accompanies the viewing of a scene (i.e., whenever a theme is instantiated in the film, that theme's name is presented in colored print that overlays the
film, accompanied in parentheses by a subtheme designation). Of course, the problems of ill-structuredness apply at the level of subthemes as well: Subthemes lack definability in the same way that concepts do and, like ill-structured concepts, must have their uses shown or demonstrated.

**A Note on “Situated Cognition” and the Relative Importance of Conceptual Knowledge.** A popular call has been raised recently for "situated learning" (e.g., Collins, Brown, & Newman, 1989). The emphasis that has been placed on situations at the expense of conceptual knowledge has led some people (although not Collins et al.) to suspect that abstract conceptual knowledge is relatively unimportant, that all that matters are the situations or cases in which learning occurs. The emphasis in Cognitive Flexibility Theory is clear: Concepts and cases are both essential. However, conceptual knowledge must be taught in the context of actual cases of its application (not "in the abstract"), and the ill-structured nature of the use of conceptual knowledge must be acknowledged and directly addressed in theories of learning, knowledge representation, and instruction. The approach of Cognitive Flexibility Hypertexts is intended to effect an integration of conceptual and situational learning, in which each is appropriately thought about in terms of the other.

**Theme-Combination-Based Exploration: Avoiding Compartmentalization and Assembling Higher Order Knowledge Structures**

An important feature of Cognitive Flexibility Hypertexts is their ability to search for mini-cases that are instances of some combination of abstract concepts. For example, the KANE program has a menu option that allows for traversals of the film (i.e., re-edited scene juxtapositions) to be selected that highlight combinations of themes.

**Non-Insular Treatment of Themes.** A common problem in traditional instruction is compartmentalization: Conceptual areas that are highly related are presented in separate chapters, lessons, classes, and so on. As a result, the knowledge ends up being represented as if it were in separate compartments. When knowledge from across compartments later has to be combined for use in some situation, the representational basis for the conceptual combination is weak. In ill-structured domains, conceptual combination is the rule rather than the exception. Thus, by allowing the film to be explored as a function of theme-combinations, students learn about the patterns of interaction of conceptual themes, their context dependencies (i.e., the way theme meanings are altered by the context of other themes that they occur with), and so on. These lessons (as well as KANE's approach to teaching several themes in the context of each mini-case scene) help to vitiate the force of the compartmentalization bias and to provide knowledge and skill for processing conceptual information in a noncompartamentalized way.

**Thus, not only is there a multiplicity of themes, but they function as something more than a list of independent items. As befits an ill-structured domain, the themes are not treated as insular, separable "compartments"; rather, the themes are shown to interpenetrate, to have complex patterns of mutual dependence on each other.**

**Schema Building.** Another use of the theme-combination feature is in generating hypotheses about complex structural models of the film, and then enabling explorations to test and refine those models. These hypotheses can be triggered by such things as chance observation of patterns in the haphazard exploration of theme co-occurrences (i.e., noticing two themes going together in a few different scenes). Or they can be explicitly suggested by the film itself (as in the example presented in the second paragraph following). Or, by exploring small combinations of themes, larger explanatory structures are suggested (also illustrated here). These hypothesized larger structures can then be explored using theme-combination search to validate the hypotheses. This kind of activity provides practice in situation-sensitive schema assembly (e.g., preparing to write an essay, as in the example in the second paragraph following), as well as helping to build "mini-schemas"—complex theme combinations that have partial applicability.

An example of a mini-schema would be the combination of the Wealth Corrupts and the Ousted Ambition themes, as in "Kane's tendency as he got older to buy things instead of earning accomplishments [Wealth Corrupts theme] interfered with the attainment of his earlier ambitions [Ambition theme]." One could then test this mini-schema or examine its variability across instantiations in the same way that variability for a single theme is learned, namely, by juxtaposing a set of scenes that constitute instances of the theme combination.

A lengthy example of using KANE to build a higher order schema (a complex model) is the following sequence of steps using the program to answer an essay question: **Why did Kane fail to achieve the ambitions which seemed within his grasp during his more youthful years?**

A start toward assembling knowledge to answer this question might come from the mini-case scene that immediately follows the one presented in detail earlier in the chapter (the "gas in the lamp" scene). After Kane says that he wants his newspaper (which he equates with himself) to be "as important to New York as the gas in this light", his friend Leland asks him how he is going to achieve that goal. Kane goes on to say that he will do it by putting a "Declaration of Principles" on the front page of the paper. He will be honest with the citizens
of New York, he will look after the interests of the disenfranchised, and so on. His associate Bernstein pointedly responds by telling Kane “You don’t want to make any promises you’re not going to be able to keep.” Kane says that he will keep these promises. That is, he will achieve his ambition for the newspaper (and thus himself) by principled behavior. This suggests a possible relationship between the Ambition theme and the Principled Behavior theme. Another part of the puzzle might suggest itself if the student recalls another mini-case scene: at a difficult moment Kane states with some gravity that he could have been a great man if he had not been very rich. Summarizing thus far, we have three themes that might figure in an answer to the question about Kane’s failed ambitions: the themes of Principled Behavior, Wealth Corrupts, and, of course, Ambition. The hypothetical model for responding to the essay question at this point might have the form “Kane’s ambition was thwarted by his wealth interfering with the path he had chosen to attain his ambitions, principled behavior.”

This suggests a re-editing of the film to look at the joint occurrences of these three themes. After the program executes the search, among the scenes encountered will be one mini-case that is especially provocative. The newspaper has become a huge success, and Kane and the staff are celebrating at an extravagant (and mildly decadent) party. Kane is about to embark on a vacation trip to Europe, and Bernstein stops the party to ask Kane if he intends to buy a lot of statues while abroad. Kane says yes, and then Bernstein keeps saying, with emphasis as indicated, “Promise me, Mr. Kane. Promise me.” There is no apparent reason for Bernstein to go on and on about Kane promising him that he will buy those statues (at least when viewing the film sequentially). However, in the context of having recently encountered the scene in which Bernstein pointedly suggested to Kane that he not make any promises he was not going to be able to keep, a clear link is established to the principled behavior that was mentioned in that scene as what was going to make the newspaper and Kane great. Once that allusion to the earlier scene is established, it becomes especially significant that Kane responds to Bernstein: “Yes, I promise you. But you don’t expect me to keep any of those promises, do you?” Clearly, the whole unusual interchange about promising (as well as Bernstein’s earlier unusual emphasis on Kane not making promises he could not keep) is intended to signal a connection between the two scenes (or at least supports such a connection, if it was not intended), a connection that is portentous for the theme of Kane’s failed ambition. What might have seemed to be a trivial (although odd) statement about making promises now takes on an enriched meaning by its juxtaposition with a more serious scene that also had an odd emphasis on promising (tied to Kane’s promise of principled behavior as a way to make him and his newspaper great). Furthermore, the point about Kane not keeping any of his promises is made in a context in which Kane has begun to clearly show that he is allowing his wealth to corrupt him (i.e., in several scenes, obvious connections have been drawn which tie unprincipled behavior by Kane to the corrupting influences of his wealth, as revealed by having the computer do a two-theme search. For example, he repeatedly indicates that he thinks he can act in an unprincipled manner towards friends and then buy them off.

Indeed, after the “promise me” scene at the party, Kane does begin to slide downhill, his lofty ambitions fading further and further from possibility with the passage of time.

Thus, the Kane program provides a substantial start toward a cohesive interpretation of Kane’s failed ambitions in terms of his renunciation of principled behavior because of the corruption of his wealth. Especially striking is the way the program helps to make connections that would otherwise be very difficult to make. Of course, this is only one of many possible responses to the essay question. What is important is that the Kane program helps students to respond to situational demands in a manner that is original, complex and warranted (i.e., the program helps the student to assemble justification for a budding complex interpretation). After a short time working with the Kane program, very intricate weavings of themes, of the kind just illustrated, become very straightforward.

### Sequencing to Produce Cognitive Structures With Woven Interconnectedness

A topic that we do not treat in detail in this chapter and that is not yet fully implemented in the Cognitive Flexibility Hypertext systems is sequencing and arrangement. Following Wittgenstein (1953), we consider the strength of representations in ill-structured domains to depend not on a single thread running throughout—that is too reductive of the domain’s complexity—but rather on the overlapping of many strands. This criterion increases the possible hinges for schema or precedent assembly, the number of access retrieval routes in memory, and so on. So, it is not just important that a domain’s landscape be criss-crossed—how it is criss-crossed is an important consideration. Of course, it should be criss-crossed in such a way that useful instructional contrasts are highlighted. Furthermore, sequential arrangements should be such as to promote knowledge representations characterized by highly woven interconnectedness along several conceptual dimensions, rather than highly compartmentalized structures with connectedness of many elements determined by some single organizational system.

One important sequencing principle that we will incorporate into our systems is that of “intermediateness”: Mini-cases should be sequenced for presentation in such a manner that two representational extremes will be avoided. First, a case should not be the next one presented if it would too closely parallel the thematic interactions in several recently presented cases;
this would help students to avoid overgeneralizations, a major hazard in ill-structured domains. Second, at the other extreme, a case should not be so dissimilar from those that were recently presented that it would give the learner the mistaken notion that there is no role for conceptual abstractions that extend across cases; this would help students to avoid the perception that each case is unique. Rather than either of these extremes, cases should be selected because their strength of relation to preceding cases is intermediate, partially overlapping and partially nonoverlapping (see Spiro et al., 1987). This would promote an appreciation of the importance of both knowledge-based and case-based analysis, without either assuming precedence over the other.

The KANE program allows for both experimenter-controlled and student-controlled sequencing. The program keeps track of student-selected traversals. The relative efficacy of different sequencing patterns in the nonlinear presentation of materials, or of different patterns of spontaneous student exploration, is a central concern of our theory, and one that is deserving of considerable empirical investigation generally.

Other Features

There are many other features of the KANE program and Cognitive Flexibility Hypertexts that cannot be discussed in this chapter because of reasons of space (e.g., options related to user-customization; user- and teacher-construction of interpretive essays—for example, one has been built for the famous reference to Rosebud in KANE; and active-lerner participation). We have focused in this chapter on those features that cast the most direct light on the most important theoretical underpinnings of the instructional approach.

To take just one example of a potent feature that can not be discussed in depth, consider the “special initiative” option, which allows for the easy development and use of mini-case sequences that illustrate new themes not covered in the provided set. Obviously, this option makes the computer program more flexible. However, it also has some cognitive significance. For example, this option increases the program’s power to deal with thematic combinations. Because the “special initiative” option presents specially programmed sequences that are accompanied by their thematic overlays, one can be thinking analytically about the various themes represented in a scene at the same time that a symbolic feature, the topic of the special initiative, is affectively “coloring” that thematic analysis. For example, if snow is supposed to symbolically evoke feelings of contentment and security associated with childhood, that mood can be experienced in the background while one is consciously thinking about the role of the Wealth Corrupts theme in the same scene (just as, when you are angry, you can be thinking about something unrelated to your anger, but be doing it angrily—the emotion effortlessly overlays the other cognition). Thoughts about one topic can be colored by the feelings evoked by another topic, thus expanding the scope of possible literary understanding and mental representation (Spiro, Crismore, & Turner, 1982).

Generality of the Approach Demonstrated by Parallels to KANE in Cognitive Flexibility Hypertexts for Random Access Instruction in Other Domains

We have stressed the point that the approach taken in the KANE program is based on principles of random access instruction derived from Cognitive Flexibility Theory (Spiro et al., 1987; Spiro et al., 1988). It is very important to make clear that that theory has the same implications for random access instruction in other, very different domains. That is, the systematic, theory-based approach in Cognitive Flexibility Hypertexts is domain-independent—essentially the same hypertext approach may be employed across ill-structured domains. There are currently two other functioning hypertext prototypes besides KANE, one in cardiovascular medicine and one in military strategy. All three of these Cognitive Flexibility Hypertexts have the same primary features discussed in this chapter (as well as many others we did not have time to present here). All of them: are organized around mini-cases (e.g., parts of battles in the military strategy program); impose multiple conceptual perspectives on each mini-case; allow for concept-based search across cases (highlighting conceptual variability of application and instances of conceptual combinations; provide commentary on the relationship between conceptual and case elements (i.e., they teach the concepts in the context of cases and show how the concepts have to be tailored to the individual case); and so on. (The Cardioworld Explorer hypertext is discussed in Spiro et al., 1988. A detailed treatment of all of the hypertexts will be found in Spiro et al., in preparation, a paper about hypertext generally and about our approach specifically.)

However, by claiming domain-independence for our hypertext approach we are not saying that we dispute the widely reported findings of domain-dependence in cognitive science. In fact, there are extensive differences in the nature of knowledge and in the way the knowledge must be used between the domains of literary interpretation, biomedical cognition, and military strategy. However, as we mentioned before, it is not the same thing to say that two landscapes are radically different as it is to say that there are important principles of landscape exploration that are general across domains (e.g., multiple representations; repeated presentations in different contexts; etc.)—it is principles of the latter kind that form the basis for the commonality of Cognitive Flexibility Hypertexts across domains. When the specific content of a domain is used to instantiate the general frame that underlies
Cognitive Flexibility Hypertexts, domain-specific features emerge. Again, the fact that the same primary features were successfully incorporated into hypertexts for three highly dissimilar domains attests to the generality of this theory-based instructional approach.

7. Cognitive Flexibility and Hypertext

BENEFITS OF THE COGNITIVE FLEXIBILITY APPROACH TO RANDOM ACCESS INSTRUCTION: DEVELOPING KNOWLEDGE REPRESENTATIONS AND COGNITIVE PROCESSES APPROPRIATE TO ADVANCED LEARNING IN COMPLEX AND ILL-STRUCTURED DOMAINS

The application of Cognitive Flexibility Theory to advanced instruction using computer hypertexts, as illustrated in this chapter by the KANE program, results in several major benefits. These can be briefly summarized as follows here.

Toward a New Incrementalism: Tractability of Learning and Instruction Without Inhibiting the Acquisition of Complexity by Early Oversimplification

The attention to covering necessary complexity is not achieved at the expense of overwhelming and confusing the learner. By using bite-size chunks of complexity in the early stages of advanced instruction (mini-cases), followed by the use of more complete cases later, instruction that addresses complexity may be introduced from the outset because it is staged in the context of a limited and manageable (but nevertheless moderately rich and ecologically representative) example—that is, the use of mini-cases reduces the cognitive demands on the learner without the hazards of oversimplified "concepts-first" approaches. (A number of other features of our approach also help learners to manage the complexity that is presented, including the various options available to the learner to get theme commentary and guidance, stage-setting information, scene re-viewings, verbal overlays of active themes during film viewing, and so on.)

Advanced Learning In Instructionally Reasonable Amounts of Time: Accelerated Acquisition of Case Experience

Another problem associated with the need to cover complexity and to cover a large number of cases (a prerequisite of advanced performance in ill-structured domains) is the amount of time required. It would be desirable to achieve these goals in the time available for instruction (i.e., a course, or a program of study). The process of acquisition of complex case experience is accelerated in our approach by the use of elaborated mini-cases and by making use of the same, increasingly familiar mini-case in different contexts (thus eliminating the need to spend time learning as many new cases). Thus case experience can accumulate far more rapidly with this approach than it does in either: (a) case-based curricula that spend much more time on each case (again, you need to see lots of cases in ill-structured domains because of the many different forms cases assume), or (b) the natural exposure to case experience (which is haphazard, and thus not tailored to instructional needs, or guided as to properties of conceptual structure).

Teaching Concepts-in-Practice: Avoidance of Over-Reliance on Knowledge-Based or Case-Based Representational Extremes

The way that advanced topics are usually taught in instructionally reasonable amounts of time is by stressing abstract conceptual knowledge at the expense of exposure to cases. The hope is that the abstractions will have wide scope of application to new cases. In an ill-structured domain, this is a vain hope. For one thing, in an ill-structured domain, concepts vary too much in the way they apply to cases. Cognitive Flexibility Hypertexts like KANE directly address conceptual variability across cases of conceptual application. And these hypertexts suture the teaching of concepts in the context of actual cases, demonstrating how concepts are tailored to cases. Thus, our programs neither neglect cases to teach concepts, nor concepts to teach cases—both are taught in the context of each other. Learning is situated, but abstract knowledge is not ignored. Our approach teaches concepts and cases simultaneously, not separately: concepts-in-practice.

Avoidance of Counter-Productive Compartamentalization

A serious problem in the preparation for knowledge transfer by traditional instruction is the presentation of information in highly compartmentalized forms. Different conceptual topics are treated in different parts of texts and at different times. When cases are presented, they are usually dealt with in isolation and very seldom related to other cases. But in an ill-structured domain, knowledge can rarely be used intact—parts of topics/schemas/concepts must be combined to form schema-assemblies, and cases must be combined with other cases to form precedent sets. These processes are inhibited by the compartamentalization of knowledge representation that results from compartamentalization in instruction. In our approach, compartamentalization is avoided in a number of different ways. Several themes are simultaneously considered when each mini-case is being processed. Search for examples
of any possible theme combination is facilitated. Commentary on one theme will contain allusions (cross-references) to other themes.

Similarly, the likelihood of compartmentalization by cases is minimized. An intact case is less likely to be rigidly treated as a monolithic entity after having been broken into several mini-case segments. Also, the multiple conceptual codings of each mini-case causes it to fall into several conceptual categories. And the ubiquity of case juxtapositions when using the KANE program, as well as the allusions to other cases in the theme commentaries and the thematic overlap across cases, are all designed to build interconnections among cases, not separation.

Teaching Situation-Adaptive Knowledge Compilation: From Intact Schema Retrieval to Schema Assembly

Schema and precedent assembly, as opposed to intact schema retrieval, is, again, a crucial tenet of Cognitive Flexibility Theory. You cannot have a prepackaged schema for every situation you will encounter in an ill-structured domain. A new case will be kind of like an aspect of one prior case, kind of like an aspect of another prior case, and so on. Similarly for the relevance of parts of different concepts, appropriately assembled to fit the new case. So you need to build schemas to fit new situations. This requires flexibility in knowledge representations. For flexibility you need many movable/recombining knowledge elements (meaningful fragments of knowledge—“partial theories”) within a web-like structure. This is accomplished in Cognitive Flexibility Hypertexts by such features as the use of miniscapes/scenes (for later precedent assembly) and by having a fairly large number of wide scope themes/schemas/perspectives for conceptual schema assembly. The larger the available set precedent cases and conceptual perspectives, the greater the likelihood that you will have an optimal combination for dealing with the odd new case. The more pieces you have to work with that each make some nonoverlapping contribution compared to the others, the greater the adaptive flexibility you will have to respond to complex and changing case realities. As we said earlier in the chapter, an ill-structured domain must be substantially deconstructed (while retaining complex interactions of the parts) in order to have a wide range of possible reconstructions. And facilitating the adaptive assembly of these pieces of cases and fragmentary “theories” is the earlier record of and experience with criss-crossing them during instruction (e.g., assembly routes are suggested—you can get between more places in the landscape in more different ways by having a rich network of interconnecting routes).

So, for schema assembly you need: (a) lots of little pieces of reality (mini-cases) and of conceptual knowledge (multiple themes/concepts/partial theories), and (b) a way of assembling them, of putting them together to fit a new case. These needs are supported by features of the approach such as theme combinations, repetition in new contexts, the more rapid accumulation of experience due to the use of compacted and elaborated mini-cases, and single theme search. Consider single theme search: It demonstrates that even routes with the same theme-name can be differentiated, which allows you to even better tailor your knowledge to highly diverse and complex new cases: You can pick just the right flavor of thematic connection—your palette for painting case reality has a much richer and more subtle range of colors. All of the other features similarly contribute to promoting schema assembly ability.

ADDRESSING SOME PROBLEMS IN HYPERTEXT METHODOLOGY

The work on KANE and the other Cognitive Flexibility Hypertexts contribute many new ideas to the growing literature on hypertext methodology. Two especially important ones are addressed here. First, the use of hypertext is made less daunting for the student. Second, it uses a procedure that automatically generates connections, rather than having to have all links stored in advance. These are discussed in turn. (Of course, we consider the most important contribution to be the theoretical one that is the subject of this chapter.)

How to Avoid the Problem of “Getting Lost in Hyperspace”

A common problem with hypertexts is that the user soon gets lost in a labyrinth of connections, and loses track of the sense of his or her exploration, as well as his or her physical place in the hypertext (collectively referred to as “getting lost in hyperspace”). The use of a case-centered instructional scheme with mini-cases as instructional and programming foci solves this problem. You can never get lost because you are never more than one connection from the focus of instruction. In a sense, each mini-case, begins a complete and independent unit of instruction. All departures for commentary, guidance, context setting, and so on, take you right back to the case at hand. Each mini-case starts a new lesson (constitutes a new experience).

Latent Rather than Programmed Links: Multithematic Coding of Cases

In conventional approaches to hypertext development (e.g., those using HyperCard), it is usually the case that any connections between knowledge nodes (between “note-cards”) that will be available for the user to explore have to be anticipated and explicitly built into the program. This is a limita-
tion of most hypertext programs that does not apply to Cognitive Flexibility Hypertexts. By coding each mini-case with a vector of relevant themes, the KANE program automatically generates instructive case sequencings (and many times more of them than would be possible if all links had to be pre-stored—the number of mini-case juxtapositions is so large a number because very many mini-cases are used, and there are many values in the search vector for each of them). So the program can be used for much longer without duplication of instruction and with many more lessons being taught.

We have seen how connections are automatically identified by the program for presentation to the user. But the mere juxtaposition of cases (even with appended commentary) does not guarantee that important connections between them that are not explicitly drawn out will be represented in the mind of the user. How, then, do the connections that are implicit in the program get formed in the mind (e.g., connections across mini-cases)? The same way they are in actual experience. After all, the computer program merely presents experiences (albeit, stripped down to their structurally-relevant features). However, the experiences in Cognitive Flexibility Hypertexts are different from actual experiences in several important ways that make it easier to induce interconnected knowledge representations from exposure to cases: (a) the cases are immediately juxtaposed (hours or days do not pass between nonroutine cases); (b) the cases are thematically related (whereas there is no guarantee of instructive relatedness across naturally occurring adjacent cases); (c) the cases are stripped down to structurally significant features, making it easier to extract dimensions of structural relatedness; (d) the cases are accompanied by expert commentary and guidance; and, finally (e) because the cases are short, they are each easier to remember and more of them can be presented in a short amount of time, facilitating the recognition of relationships across cases.

CONCLUSION

The overall effect of the features of random access instruction that are derived from Cognitive Flexibility Theory and embodied in “Exploring Thematic Structure in Citizen Kane” is a program that allows the Kane character to be viewed from a very large number of valid perspectives. The result of overlaying more and more points of view on the same content material (while at the same time reducing initial demands on the learner resulting from this extra complexity by working with easily digestible mini-cases) is a kind of “stereographic” representation—the multidimensional fullness of the content is increasingly approximated with each additional perspective that is presented. Furthermore, the theme combination feature of the program permits an incremental buildup of a picture of the interrelations among the thematic perspectives. Instead of just having a set of independent conceptual perspec-

tives that have to be additively assembled, the complex pattern of their intertwining in the actual cases (scenes) can emerge. By re-presenting the same information in different contexts and from different perspectives, the complexity of that information is made more resistant to oversimplification.

As a result, knowledge representation is made more multidimensional—and knowledge that will have to be used in many different ways has to be represented in many different ways, with the potential to form various combinations with other aspects of knowledge as required by new contexts of knowledge use.

The result of instruction of this sort is deeper understanding of complexity and nuance, understanding that provides learners with a basis for going beyond what was explicitly taught. In ill-structured domains, there is considerable variability in the way knowledge has to be used across the set of potential knowledge application situations. Correspondingly, there is a greater burden on learners to be able to independently apply their knowledge, rather than relying on prepackaged “prescriptions” for knowledge application provided by teachers and textbooks. Therefore it is essential that learners be presented with a cognitively tractable picture of the landscape of varieties of knowledge use. And learners must be guided in the development of cognitive skills for effectively traversing those landscapes to independently and adaptively assemble knowledge to fit the new situations that that knowledge must be applied to. These are the aims of the hypertext instructional systems that implement Cognitive Flexibility Theory. In Cognitive Flexibility Hypertexts (like “Exploring Thematic Structure in Citizen Kane”), these aims are achieved in an instructional environment that reconciles agendas whose seeming incompatibility would be expected to impose extreme obstacles: Instructional material is presented in a manner that does not sacrifice complexity, yet takes an instructionally reasonable amount of time to cover, and does not overwhelm the learner.

A final point: The instructional approach described in this chapter is difficult. But sometimes advanced knowledge acquisition has to be hard. There are data that indicate that difficult instruction tends to be neglected, at great cost to learning outcomes (Feltey, 1989; Spiro et al., 1988). The trick is to make advanced learning as easy as possible without sacrificing the integrity of the material to be learned. That is what Cognitive Flexibility Hypertexts attempt to do.

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REFERENCES


