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COMBINING CONCEPT MAPPING AND ADAPTIVE ADVICE TO TEACH READING COMPREHENSION

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13. ABSTRACT *(Maximum 200 words)*

This paper describes a computerized learning environment for teaching the conceptual patterns of critical literacy. While the full implementation of the software treats both reading and writing, this paper covers only the reading aspects of R-WISE (Reading and Writing in a Supportive Environment). The software described posits the computer as an environment, where scaffolding and adaptive advice gently guide the fledgling learner through complex, multi-dimensional intellectual activities. The software encourages students to practice powerful strategies for reading comprehension in a computer-mediated environment that fosters guided-inductive learning and ensures mindful engagement in the task. R-WISE guides the internalization and self-initiation of higher-order processes and metacognition, which the novice reader is unlikely to activate without prompting.

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PREFACE

R-WISE (Reading and Writing in a Supportive Environment) is part of a seven-year Air Force effort -- the Fundamental Skills Training project -- to design, build, evaluate, and transition advanced computer-aided instruction to the education community. This research was done while Patricia Carlson was an associate at the Armstrong Laboratory, Human Resources Directorate, Intelligent Training Branch, Brooks AFB, TX, on leave from Rose-Hulman Institute of Technology. This article does not necessarily reflect the opinions or policies of the U.S. Air Force or other government agency.

This paper presents an overview of the software design and instructional strategy for the reading component of R-WISE. A companion Technical Paper, "R-WISE: A Learning Environment to Teach Prose Composition," discusses the treatment and computer delivery for teaching writing. Many people contributed to the development of R-WISE. The authors express their gratitude to the high school teachers who served as subject matter experts; the programmers who developed the software; and the research assistants who tabulated the data for the pilot study. We especially acknowledge the generous sharing of time and talent and continued support of the following individuals: Dr. Wes Regian, Senior Scientist for the Intelligent Training Branch (AL/HRTI); LtCol Jim Parlett, AL/HRTI Branch Chief; Dr. Kurt Steuck, the Fundamental Skills Training Project Manager; and Ms Teri Jackson, who oversaw the implementation of R-WISE at ten sites in five different states.

I. SUMMARY

When driven by simple models of information processing, reading instruction focuses on basic decoding skills centering on words and sentences. Factoring in advanced cognitive studies adds at least two more dimensions. First, readers must learn a collection of strategies for constructing meaning from text. Second, and most importantly, readers must develop enough situational awareness to diagnose a text and know which strategy to deploy.

Teaching intellectual crafts that involve not only base-line performative skills but also a repertoire of problem-solving heuristics, and the metacognitive maturity to orchestrate multi-leveled activities, works well in a master-apprentice model. However, one-on-one instruction is far too labor-intensive to be commonplace in the teaching of reading. Classroom innovations (e.g. collaborative learning) and redefined roles for teachers (e.g. reciprocal teaching) help to create more active learners. Also, newly devised "learning environments" use computer software to mediate between the student and the task by dynamically adjusting the cognitive demands so that the student is always challenged but never overwhelmed.

This paper describes a computerized learning environment for teaching the conceptual patterns of critical literacy. While the full implementation of the software treats both reading and writing, this paper covers only the reading aspects of R-WISE (Reading and Writing in a Supportive Environment).

II. INTRODUCTION

Reading Strategies and Metacognition

Research into the cognitive aspects of reading has led to something of a theoretical framework to guide instructional development. For example, awareness that good readers have a repertoire of problem-solving behaviors for various types of tasks and texts launched a new pedagogy for strategy acquisition. The literature for practitioners features a number of techniques for teaching young readers to diagnose levels of understanding and to repair mistakes in comprehension. These routines vary from rather elaborate mnemonics for complicated, multi-stepped procedures (as in the well-known S4R or SQ3R protocols) to thinking frames (graphic representations that support the deconstruction of text into units of meaning).

Unfortunately, strategy training has fairly low durability (Garner, 1987). Part of the reason for this degradation may be, as suggested by Garner, that the teaching of a specific strategy becomes an end in and of itself, divorcing the skill from the multi-dimensional context of mature reading (p. 123). For example, the concept diagrams advocated by Armstrong and Armbruster (1991) require that the learner become comfortable with a sophisticated set of conventions for mapping out ideas. Additionally -- at least until the learner becomes proficient at using this new visual nomenclature -- the teacher must compose the empty maps for each piece of reading. The issue is that such essentially self-contained exercises seem to bear little resemblance to the dynamic, fluid process of comprehending a piece of text in the real world. The adept reader not only has a repertoire of strategies at hand but, more importantly, has the metacognitive ability both to anticipate and to detect abstract problem-types and then to deploy, adapt, combine, or abandon strategic cognitive solutions.

Paris and his colleagues on the Informed Strategies for Learning (ISL) program demonstrate what can be done with a more holistic/naturalistic approach for teaching reading comprehension (1984). The program has three distinct qualities. First, well-designed lessons explicitly model a set of comprehension strategies. Second, students are encouraged to develop both cognitive and metacognitive capabilities -- or the ability to think and the ability to think about thinking. Third, the layered curriculum moves gradually from explicit instruction in strategies to increasingly asking the student to initiate, apply, and evaluate the success of an approach (Jones, et al., 1987). As important as these features are, more important is the enactment. Using discussion and exploration, the students work through the problem at hand in a collaborative-learning scenario. Additionally, the teacher's role changes from dispenser of information to facilitator and mediator in a process of group learning.

Computers as Cognitive Tools

Stepping out of the routine of traditional, teacher-centered classroom instruction and into a collaborative learning situation constitutes a very significant change in American pedagogy. A concomitant sea change is underway with increased interest in the potential for computers to partner with the learner -- just as a peer or a teacher would. This notion of "intelligent applications" (or IA versus AI, sometimes called "mindware" or "cognition enhancers") posits the computer as a learning environment, where scaffolding and adaptive advice gently guide the fledgling learner through complex, multi-dimensional intellectual activities.

For example, Marlene Scardamalia and Carl Bereiter have reported on their extensive work with computer-supported intentional learning environments (CSILE) that "foster rather than presuppose the ability of students to exert intentional control over their own learning" (1989, p. 52). Rather than the brittle structures characteristic of traditional CBT, these interactive workspaces follow a cognitive apprentice model and focus on helping students "learn how to learn, learn how to set cognitive goals, learn how to apply effective strategies for comprehension, self-monitoring, and organization of knowledge" (pp. 51-52).

Gavriel Salomon and his associates also present a compelling case for computer-supported instruction where the machine partners with the learner -- much in the fashion of the socio-developmental model described by Vygotsky's "zone of proximal development" (1978). This term is used to explain the mentoring that occurs between master and apprentice and between peers during collaboration. Salomon (1988, 1989, and 1991) and Zellermayer (1991), among others, use the term "cognitive tool" to suggest that the computer can partner with the novice and provide the guidance that allows the novice to practice the more robust problem-solving behaviors of an expert. Unlike computerized productivity tools (such as word processing) whose effectiveness stems from their convenience, a "cognitive tool" teaches mental models for understanding and a procedure that can be self-initiated in the absence of the technology. (For example, consider the abacus as a concrete device for accomplishing the abstractions of arithmetic manipulations.) Like AI in reverse, manipulating the machine fosters new, more powerful habits of mind for the learner (Salomon, 1988).

Goals for R-WISE

R-WISE follows Salomon's definition of a "cognitive tool." The software encourages students to practice reading comprehension in a computer-mediated environment that fosters guided-inductive learning and ensures mindful engagement in the task. More specifically, R-WISE:

- Eases demands on short-term memory and helps to focus attention on strategically important aspects of comprehending text.
- Guides the internalization and self-initiation of higher-order processes and metacognition, which the novice reader is unlikely to activate without prompting.
- Explicitly models the strategic intellectual processes so that the floundering student avoids what Britton, et al. (1985) have termed the lower level components of text processing, or becoming increasingly entangled in descending levels of mental actions, finally concentrating all energy on such things as word recognition, syntax decoding, and literal meaning to the exclusion of larger concerns of semantics, disambiguation, meaning, and knowledge construction.

III. SOFTWARE COMPONENTS AND INSTRUCTIONAL APPROACH

The process model of text comprehension underscores the idea that good readers know that **making meaning** from prose is an interactive process while poor (or immature) readers attempt to slavishly **extract meaning** from the text by decoding word-for-word. Characterizations of these two modes of "reading" are almost diametrical. The poor reader (1) does not vary speed or technique based on text type, (2) does not know how to exploit the "signposts" built into conventional text forms, (3) cannot glean meaning for unfamiliar words and concepts from the context, (4) cannot tell when a statement makes no sense within the confines of its presentation, and (5) has difficulty making "text connecting" inferences as well as reasoning about probable outcomes of information presented in the text. The antithesis, as practiced by good writers, is characterized by (1) guided planning and situational diagnostics, (2) rich mental representations of text possibilities for a wide range of scenarios, and (3) a robust "executive control program" for allocating mental resources and for handling the tremendous cognitive load of deep-processing text.

R-WISE addresses these issues of critical literacy and teaches the use of language as a vehicle for critical thinking. We have developed a battery of "procedural facilitators" staged so as to promote progressively more sophisticated forms of reading comprehension. Specifically, R-WISE promotes three qualitatively different types of activities and models each for the student: (1) identifying concepts and units of meaning in a text, (2) formulating interpretations and making inferences, and (3) metacognitive control over performative skills. Admittedly, these are not definitive categories, and it is impossible to isolate totally the activities of one from those of another. Our purpose is to work with a process-based model that is sensitive to distinctions in knowledge about decoding, inferencing, text structures and text conventions, language, reading purpose, higher-order strategies, and self-monitoring.

R-WISE uses a hybrid paradigm for interactive instruction. Part of the guidance comes from adaptive tutoring using traditional AI formalisms and part of the teaching comes from the powers of reification (or representing complex processes as manipulable objects on the computer screen). The instructional architecture is represented in Figure 1. The following sections elaborate on each of the numbered areas in Figure 1.

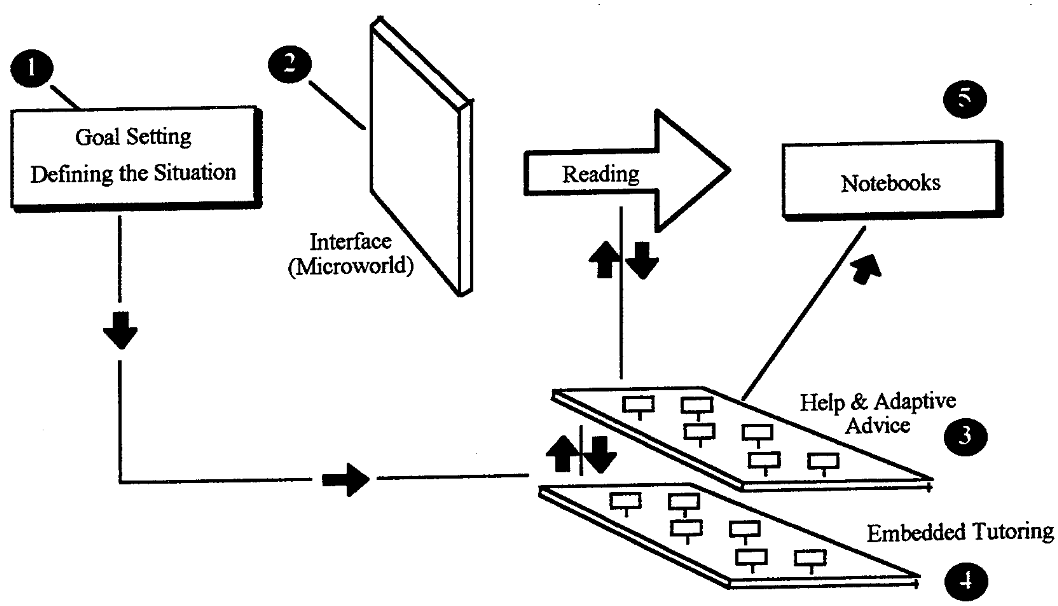

Figure 1: System Overview of Hybrid Tutoring Capabilities

Setting Goals

(Area 1 of Figure 1) The "decoder" views reading as if it were a straightforward exercise in stripping meaning from the page. For the expert, however, having an explicit, stated set of goals fosters a kind of filtering activity that focuses the task from the outset.

At the beginning of each new lesson, the student is asked to go through a preliminary activity that helps to (1) delineate the requirements of the task, (2) identify features of the text such as level of difficulty, structure, and aim of the discourse, (3) identify strengths (such as prior knowledge) and weaknesses (such as limited experience with the type of discourse) the reader brings to the situation. At this point, the student is working from a paper copy of the text and has read through the materials. A questionnaire helps the student to "preview" the elements of the task that will dynamically interact during the session. Though a truly novice user could spend much time in this preliminary activity, a more seasoned user of the software will work through the interface in a matter of minutes.

Table 1: Situational Combinations Tracked in the Frame

Area	Conditions
Author's Purpose	• Descriptive • Narrative • Expository • Persuasive • Expressive
Reader's Purpose	• Entertainment/General Knowledge (leisure) • Specific Knowledge (information) • Study (logic and content) • Appreciate Language (aesthetic)
Text Type	• Has formalized rules for text placement, such as a poem • Uses titles, section headings, and other signposts and landscaping, such as a textbook • Relies on integration of text and graphics, such as instructions for putting a device together • Makes extensive use of dialog among characters, such as a play, a short story, or a novel • Paragraphs and sentences are short, with few formal devices for cohesion, such as in a newspaper article • Paragraphs are well developed and sentences have logical connections, such as in an essay

Metacognitive awareness has increasingly become an acknowledged component of performance in complex, multidimensional tasks. In brief, metacognition means the ability to learn about learning. Though a bit "fuzzy" because such meta (or higher-order) forms of mentation are difficult to observe and measure directly, the explanatory power of this body of research has been championed by a number of researchers in the past decade (for example, Weinert and Kluwe, 1987). Metacognitive awareness is a kind of calibration among external demands, internal resources, and a desired outcome. Just as an athlete, poised before the beginning of an event, takes a moment to reflect and to visualize a goal and the path toward that outcome, so this introductory, goal-setting workspace for R-WISE encourages the student to formulate a loose plan for the cognitive task about to take place.

Just as importantly, this preliminary work "sets" the parameters for the software that supply the "intelligence" behind the adaptive advice. The tutor now has a "frame" or backplane of conditions against which further actions can be evaluated during the remainder of the session. (If the student changes goals, the frame is also updated.) Table 1 shows the combinations (or rhetorical situations) tracked. Clearly, the repertoire is rich -- 120 sets of conditions are possible at this level. This number becomes even larger and the tutoring capability even richer as these preliminary combinations are conjoined with additional datapoints drawn from the student's subsequent activities. (In a following section we give more detail on how elements of this frame become "rules" that "fire" appropriate instructional statements during the reading process.)

Microworld

(Area 2 of Figure 1) The second way R-WISE encourages the active construction of meaning during reading fits in with the current emphasis on "visual referents" for teaching abstract concepts, but is actually rooted in comprehension treatments devised as much as two decades ago. In the late 70s and early 80s, new techniques for representing text diagrammatically were used to teach students how to "see" the important relationships among ideas (Armbruster and Anderson, 1982). On the whole, these visualization strategies produce an improvement, but -- in the traditional classroom -- must be weighed against the overhead of teaching the technique and the time used in constructing the diagrams.

The interfaces of R-WISE represent visual organizers for specific intellectual processes. As explained by J. H. Clarke, "[f]rom the standpoint of cognitive theory, graphic frames mimic aspects of semantic memory structures or schemata, that learning theorists believe organize the mind" (1991, p. 526-7). For example, Figure 2 shows "Concept Mapper," the workspace that encourages the deconstruction of linear prose into a more symbolic or semantic network by helping the student tokenize higher-order mental manipulations.

Given the premise that most of the clients for R-WISE probably have learning preferences that are concrete/visual rather than abstract/language, we provide "objects" for obscure mental actions. Similar to "webbing" or "schematicizing" -- paper-and-pencil techniques used in the traditional classroom -- this technique encourages the student to formulate a "meta-view" in a simplified, visible language that cuts through much of the complexity of paper text. In addition, working with a malleable, graphical overview helps the student to recognize and to take control of the intellectual processes foundational to reading for comprehension.

The student can consult the text in the right-hand window, but the main focus of activity is in the workspace on the left side of the screen, where the student builds a model of the knowledge structure of the text passage. Using standard GUI interface conventions, the student clicks on one of five different button icons located across the top of the space. Four of these will pop out an icon representing one of four aspects of comprehension: (1) identify the main idea, (2) locate a major support statement, (3) identify a supporting detail, and (4) draw an inference from the text. Multiple occurrences of the icons are acceptable and all icons are draggable, meaning that students can use placement of the tokens to construct "a visual illustration of verbal statements" (Jones, Pierce, and Hunter, 1989). The fifth button on the control panel allows the student to link the icons appearing in the workspace. The sixth button (whose icon is an "X") allows the student to delete icons previously placed in the workspace.

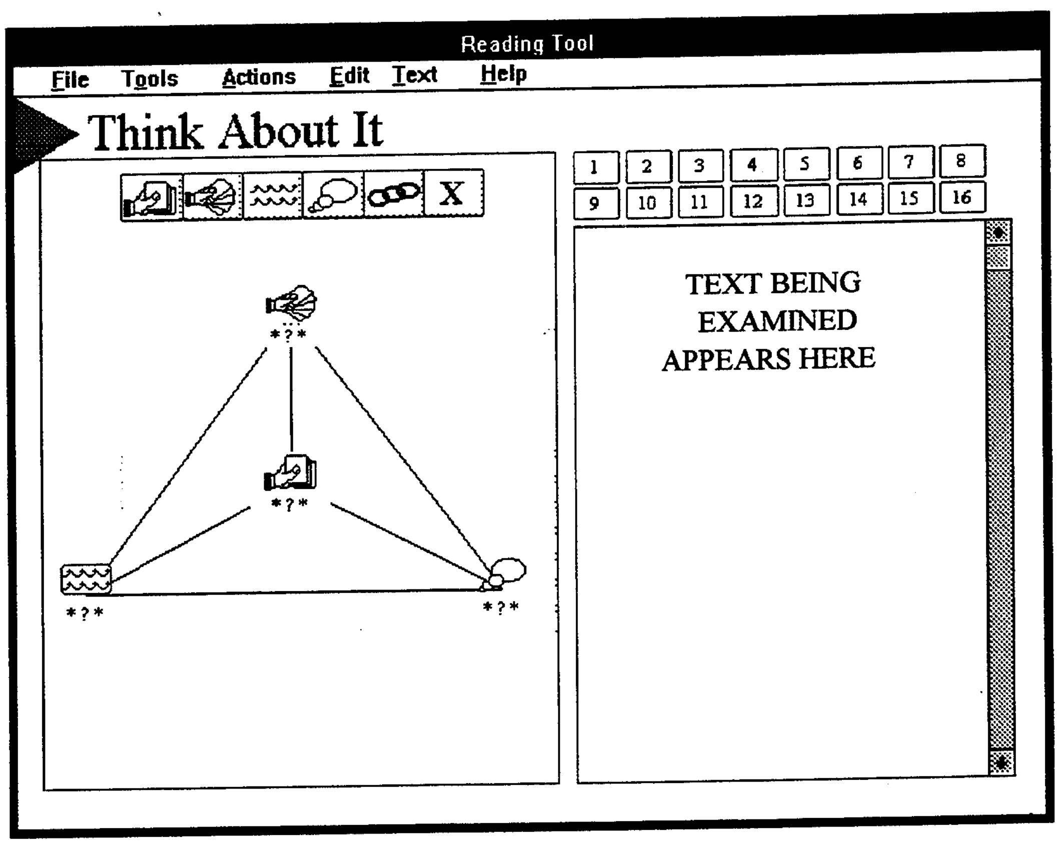

Figure 2: Interface for Concept Mapper

Strategic Elaboration of the Thinking Frame

(Area 3 of Figure 1) The process of mapping (clustering and linking) is educationally powerful in that it helps the reader to see things from a higher level or as a synoptic overview. However, even deeper processing of the concepts of the text can be encouraged by having the student elaborate on the meaning for each icon. Clicking on an icon brings up what would be considered a "properties" screen in traditional object-oriented programming, but in this context the input screen becomes a "cognition enhancer," helping the student to probe beyond the surface. As can be seen in Figure 3 the selected node opens to a split screen containing both a space for the student to write a note and a place where the computer coaches the student.

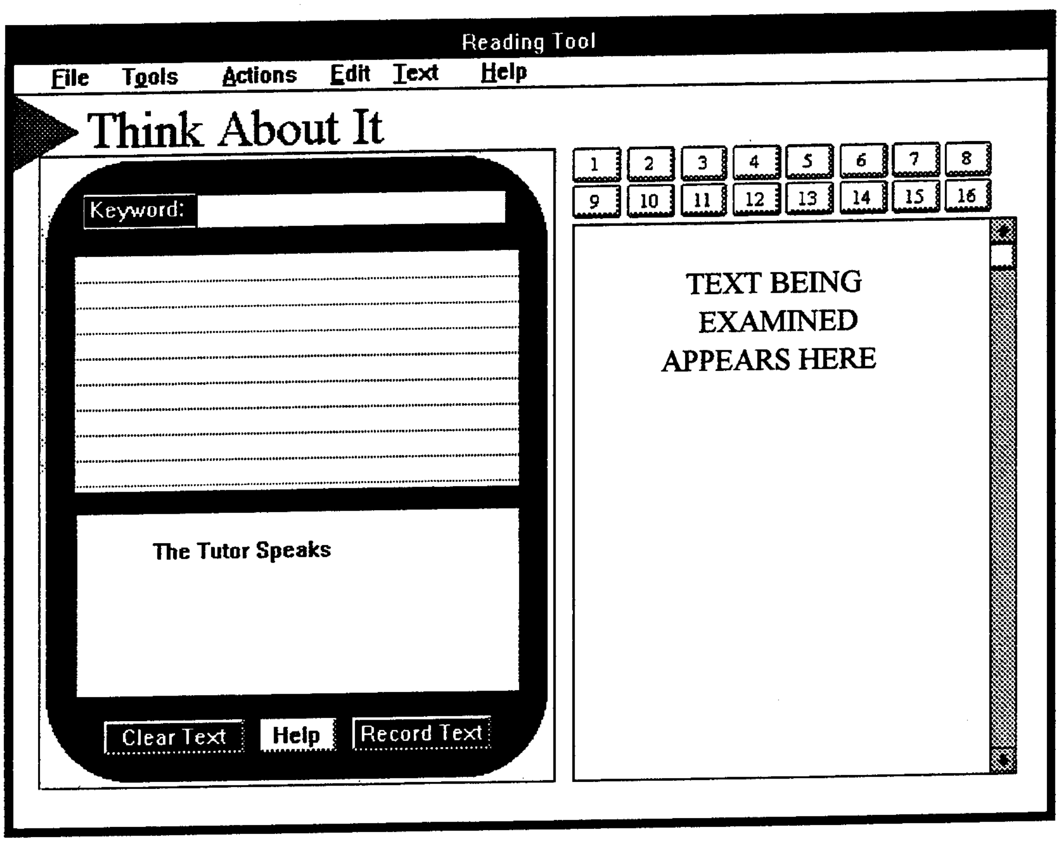

Figure 3: Interface for Elaboration of Icons

Instructional statements are generated through a kind of triangulation, based on the rhetorical situation (the several frame conditions set up in the goal-setting phase) and the moves made by the student in the microworld of the concept mapper. Monitoring the combination of rhetorical situation and place in the reading process creates a cognitive task map for accessing instructional statements.

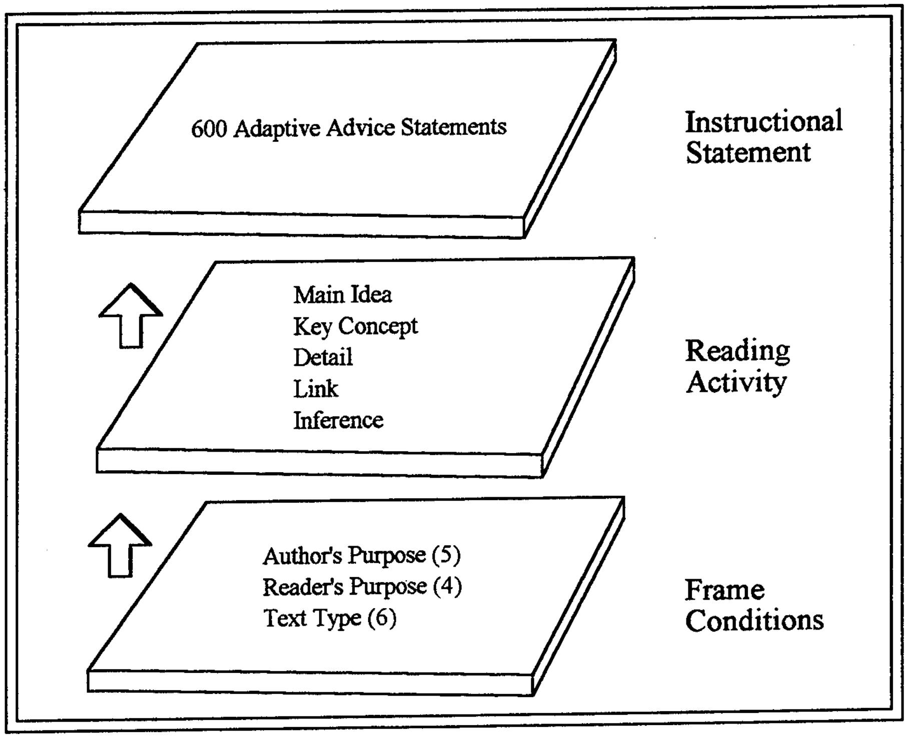

Figure 4: Elements that Determine the Nature of the Instructional Statements

Figure 4 shows the number of instructional situations captured in this tool. In writing the 600 advice statements, we addressed each combination of the four strategic elements tracked by the system: (1) Reading Activity, (2) Author's Purpose, (3) Text Type, and (4) Reader's Purpose. Three factors -- Reading Activity (e.g. drawing an inference), Author's Purpose (e.g. attempting to persuade), Text Type (e.g. a poem) -- seemed to be of equal concern in deciding what advice to give to the student. However, Reader's Purpose (e.g. reading for enjoyment versus studying) appeared consistently to carry more weight in determining the exact nature of the instructional statement. Though this started for us as an intuition, the observation is supported in the research (for example, Tierney and Cunningham, 1984). The basic theoretical framework of metacognition in complex task analysis suggests that having a reason for working a task serves to activate appropriate psychological processes and to provide a basis for effective self-monitoring (Flavell, 1987). We define the four "reasons for reading" used in our model as:

- Leisure -- Reading for enjoyment; although not as loosely structured as browsing, the reader is motivated less by task-specific requisites and more by general interest and personal preferences.

- Information -- Reading for a specific purpose; this is a goal-directed process using techniques for locating information and evaluating its usefulness for a definable set of needs.

- Studying -- Performance-related reading; the reader knows at least the general nature of the criterion task and uses more stringent methods for explicit processing (e.g. underlining, summarizing, self-questioning, and the like) for retaining content and logic.

- Aesthetic -- Reading based on appreciation for language and its manipulation; the reader focuses on the "meaning beyond the surface meaning" by processing the more affective features of tone, style, figurative language, and the like.

Lookup tables deliver the adaptive advice with accuracy and precision. Table 2 pairs the three frame conditions (from the planning workspace) with the activity node (from the concept mapper) to demonstrate how fine-grained and appropriately targeted this adaption can be.

While some computerized reading instruction contains questions, few actually embed the prompts within the dynamics of the reading process itself. None, to our knowledge, provides as extensive a typology for adaptive guidance. Although when viewed piecemeal, the advice may seem to have a random quality, the full array of adaptive guidance was designed to reflect the principles of cognitive research into the reading process. Tables 3 and 4 show how the prompts modulate over a landscape of meaning. In Table 3, all conditions are held constant except for the reader's purpose. In Table 4, all conditions are held constant except for the text type. From these examples, one can see that the advice arrays simulate "intelligent" responses.

Table 2: Examples of Instructional Statements

Plans and Goals	Node	Adaptive Advice
Author's Purpose: Expository Reader's Purpose: Logic Text Type: Text and Graphics	Inference	What is the most important part of the system being described? What would happen if this part were missing?
Author's Purpose: Expressive Reader's Purpose: Aesthetic Text Type: Poem	Main Idea	Read the stanza over. Now close your eyes and visualize the author's face. What emotion does it show?
Author's Purpose: Persuasion Reader's Purpose: Information Text Type: Newspaper Article	Detail	The author uses detail to develop or extend a position. Your plans may not match the author's. How does the detail fit in with your ideas?

Tables 2 through 4 give examples of prompts for elaborating an activity node. Making a comment on a link is a bit different. The adaptive prompts for linking direct the student to the notion of hierarchical connections. Because the four concept nodes represent an ascending order of generalization (detail, key idea, main idea, inference), linking one node with another implicitly indicates one of three relationships between the anchor (the starting node) and the target (the ending node). These relationships are (1) Generalization, (2) Specification, and (3) Association.

Table 3: Examples of Instructional Statements Showing Change Based on Reader's Purpose

Node: Inference
Author's Purpose: Expository
Text Type: Textbook
Reader's Purpose:

Reader's Purpose	Adaptive Advice
Leisure	What does the reading remind you of? Think of a similar situation you have been in or read about. Based on this past experience, what would you say is the probable outcome of what you have just read?
Information	How well does this material match what you are looking for? State your needs as clearly as possible. Does it seem likely that the next paragraph or segment will move closer to giving the information you want?
Aesthetic	State as clearly and as briefly as possible the central concept of the passage you have just read. Now finish this statement: "If this concept were a bridge, it would lead to -----."
Logic	State an outcome or interpretation of what you have just read. Now, using "backward reasoning," find elements in the passage that act as clues or as evidence for the outcome.

Table 4: Examples of Instructional Statements Showing Change Based on Text Type

Node: Main Idea
Author's Purpose: Persuasion
Reader's Purpose: Logic
Text Type:

Text Type	Adaptive Advice
Poem	Find five adjectives, or five verbs, or five images in the passage you are reading. What feeling do you get when you read these five items over as a list?
Textbook	Look at the topic sentence and the concluding sentence for each paragraph in the passage. From these clues, what would you say is the author's main point?
Instructions	Instructions such as the warning labels on dangerous equipment need to be written so that they are taken seriously. Even though what you are reading may not be a warning, how does the writer motivate you to take the message seriously?
Fiction or Play	This type of writing has plot and characters. The characters say and do things that are used to remind us of a larger message (or a theme). What larger message does this portion of the reading present?
Newspaper Article	Paragraphs in newspaper articles may be loosely organized. The sentences may seem like a list and there may not be a topic sentence. What idea do all (or most) of the sentences relate to?
Essay	This type of writing almost always uses signals, such as transitions, to show relationships among ideas. How do the signals in this passage help to find the main point?

To explain further: if a student links detail to detail or inference to inference, the connection is between two items on the same level, or Association. If the student links a detail to an inference or a key idea to a main idea, the connection is Specification (that is, the anchor provides development for the target). If the anchor is an inference and the target a detail or if the anchor is a main idea and the target is a key idea, the connection is Generalization. The prompts for linking include this additional cognitive dimension -- hierarchical relationship -- as illustrated by Table 5.

Table 5: Examples of Instructional Statements for Linking

Plans and Goals	Node	Adaptive Advice
Author's Purpose: Expository Reader's Purpose: Logic Text Type: Text and Graphics	Detail to Detail ⇨ Association	Which detail comes first and why? For example, if you are reading about a process, are these details linked either in time or in space?
Author's Purpose: Expressive Reader's Purpose: Aesthetic Text Type: Poem	Inference to Detail ⇧ Generalization	How does this detail contribute to the interpretation you have made? Does the detail form part of a pattern or does it call attention to itself because it is different?
Author's Purpose: Persuasion Reader's Purpose: Information Text Type: Newspaper Article	Key Idea to Main Idea ⇩ Specification	How does this key cluster "unpack" the main idea? If the topic were divided into parts, does this cluster deal with a central issue? Does the cluster introduce arguments for and against the claim in the main idea?

Clearly, the lists of prompts are a form of embedded instruction in verbal reasoning. However we feel that the student also learns an enriched self-regulatory capacity so that she can move out of the lower-level information processing into a higher-level cognitive activity without disrupting the whole process. This ability to suspend operations on one level and to focus mental energies on another is characteristic of the experienced reader.

Just-in-Time Tutoring

(Area 4 in Figure 1) While designing R-WISE, we carefully planned how to integrate the technology into a year-long curriculum. However, the software could be implemented as a classroom resource to be used by identified students while the teacher works with the majority of the class on another activity. As currently planned for group use in a computer laboratory, the tutor takes up about 20% of the course. The production skills necessary for reading (e.g., linear and literal decoding, word recognition and vocabulary, sentence structure and paragraph forms, variable speeds and access features of text, and other fundamentals) are not taught on the computer. This is a deliberate decision. To act as an accelerator or a learning environment, the computer has to support the process of literacy. Interrupting the process to teach the enabling skills (1) mixes levels, styles, and purposes of instruction, (2) creates breaks in the train of thought from which the student may not recover, and (3) results in a fairly unexciting electronic workbook.

While production skills and metacognitive skills are not interchangeable, they are correlated in that they must occur simultaneously in expert behaviors. As an extension of this, even though the tutor suggests a strategy in the prompt at the elaboration stage, the student may still be at a loss as to what to do. Recognizing that students may need more explanation, we have embedded short, interactive CAI components that promote focused practice in intellectual activities foundational to critical reading. Drawing from Palincsar and Brown's model of mental activities necessary for critical reading (1985), the Just-in-Time Tutoring units (JITTs) offer coordinated instruction in four areas:

- *Predicting:* Somewhat akin to probabilistic reasoning, this activity requires that the student draw a conclusion or forecast an outcome based on interpretation of a pattern of cues within the passage. JITTs in this category tutor two specific areas: (1) activating background knowledge (or schema) as cognitive frameworks for generating likely outcomes, and (2) awareness of textual structures (e.g. transitions, sentence patterns, and other devices of coherence) for bridging informational gaps in prose presentations.

- *Clarifying:* Many studies report that readers -- even mature and accomplished adults -- view text as infallible. Failure either to detect or to acknowledge informational inconsistencies increases with less mature and less sophisticated readers. Therefore, JITTs in this category tutor (1) both the ability and the appropriateness of demanding clarity from texts, and (2) how to generate a useful "fix up" strategy once a misunderstanding has been detected. Instruction is clustered around three types of obstacles to comprehension: lexical difficulties, external inconsistencies, and internal inconsistencies (Garner, p. 98).

- *Generating Questions:* In traditional instruction in reading comprehension, students are often asked to answer a set of questions about the targeted passage. Advocates of higher-order instruction in critical reading maintain that reversing the process is more effective. In this cluster of JITTs, students are given a role and a purpose emulating real-world situations and are asked to generate specific types of questions that are instrumental in solving a particular problem. JITTs in this category tutor (1) locating salient information based on a specific frame of reference, and (2) understanding the difference among prompts (e.g. questions that require recall and ones that require interpretation or insight).

- *Summarizing:* Summarizing in traditional instruction can degenerate into a kind of proforma note-taking activity. Used as a self-monitoring strategy, however, guided review becomes a means for the student to check recall of important concepts and integration of the parts into a meaningful whole. JITTs in this category tutor (1) macrorules for constructing a summary (e.g. deleting trivia and redundancy; finding superordinate categories, supplying missing main ideas), and (2) techniques for backgrounding and foregrounding information based on specific situational demands.

The student accesses a JITT from the elaboration prompt interface by clicking on the "Help" button. This action indicates that the reader wants instruction on powerful patterns for reasoning and thinking. As indicated in Figure 5, each of the seven reading activity nodes (detail, key idea, main idea, inference, and three types of linking) associates with instruction. A student having difficulty finding a main idea, for example, asks for help. A very brief thinking frame -- demonstrating how to use one of the four reasoning skills to find a main idea -- appears. The choice of Summary, Clarification, Questioning, Prediction is random. If the student cannot work with the suggested operation, she asks for another and the system moves to the next option in the stack of four.

Palincsar and Brown (1983) advocate the teaching of a minimal set of enriched thinking activities, as applied to a variety of text situations. Thus, we constructed 28 separate JITTs. Because of the common thread of the four mental manipulations, however, the JITTs work more like four themes (each with seven variations) than as 28 separate entities.

	Summary	Clarification	Questioning	Prediction
Main Idea	1	2	3	4
Key Cluster	5	6	7	8
Inference	9	10	11	12
Detail	13	14	15	16
Link ➡ (Association)	17	18	19	20
Link ⬇ (Specification)	21	22	23	24
Link ⬆ (Generalization)	25	26	27	28

Figure 5: "Anchor with Variations" Instructional Design for JITTs

Notebook Consolidation

(Area 5 of Figure 1) All the elaborations the student makes on icons in the elaboration interface are transferred to a notebook where they are available for review. As Figure 6 indicates, each map is associated with a span of paragraphs, whose number might vary from a single unit to all the paragraphs in the text. Notes are then displayed hierarchically, in descending order, starting with inference nodes. Any links made to a node are presented immediately after the target node. The type of relationship (Specification, Association, Generalization) is also indicated. The student may go to the notebook and inspect the contents at any time. These notes are more than glosses or annotations. The computer-mediated prompts emulate powerful teaching concepts and initiate a processing that is deeper and more probing than paraphrase or summary (Bretzing and Kulhavy, 1979 and 1981). These reworked versions of the text are more than a superficial variation on the original's content and connections; they are new knowledge structures combining both the organization and information of the text with enriched reworking by an active reader.

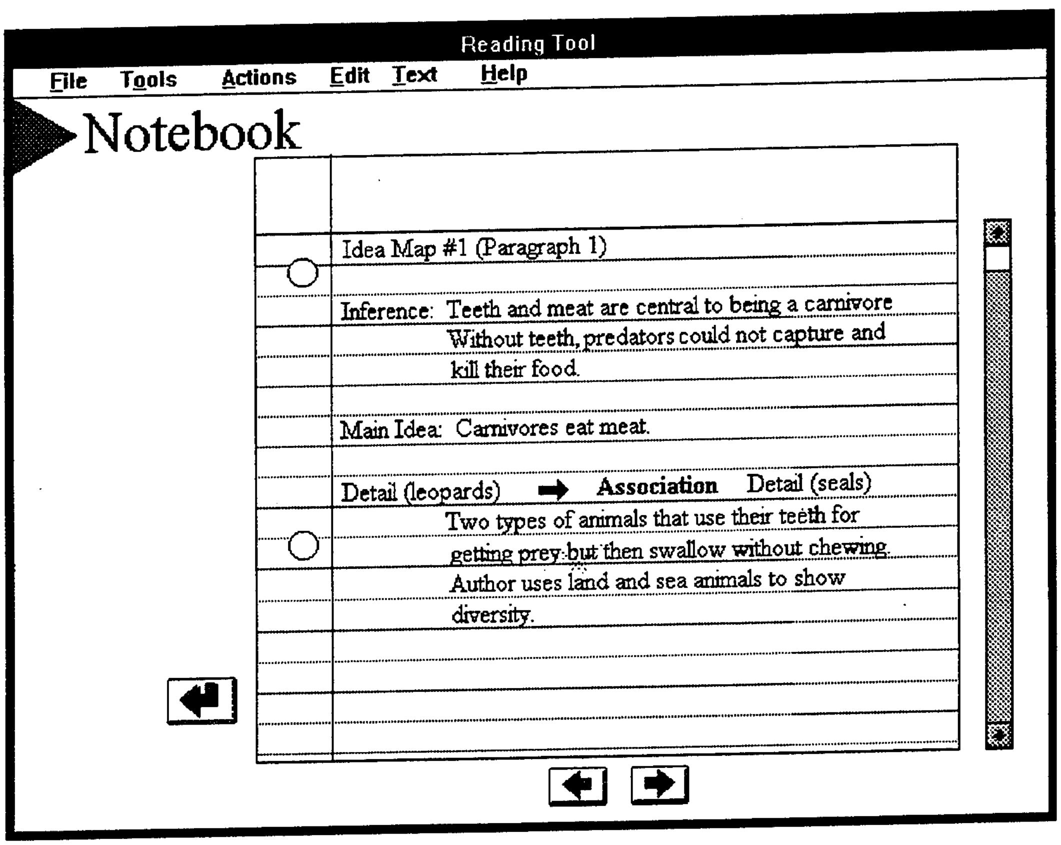

Figure 6: Sample Page of Notebook Entries

IV. CONCLUSIONS

Pairing "concept mapping" with "node elaboration" provides a loop that (1) partners with the student to reduce the mental load and (2) helps the student to enter into a self-prompting episode. This loop takes a very sophisticated, open-ended problem and pares it down to a manageable set of options for the inexperienced reader. In brief, working in tandem with a synoptic overview and with sponsored elaboration creates a rich learning environment that nurtures the following elements crucial to reading comprehension:

- The elaboration segment encourages students to examine and interlink their previous knowledge with the new knowledge presented in the text. For example, the student may be prompted to compare through analogy a point in the content with something previously known and to come up with a superordinate proposition that encompasses and explains both. Such bridging activities discourage a simple rote incorporation of the text into memory.

- The object-oriented nature of the tutor provides a visualization for obscure mental operations. Through mapping and elaborating, the process becomes sufficiently deliberate so that the student can become both an observer and a participant in these higher-order thinking skills.

- Model building and simulations are popular concepts in today's educational software. Yet, as pointed out by Salomon, et al. (1989), merely giving the student the capability to construct a visual representation is not as powerful as combining the manipulations of constructing a model with expert-like guidance. As typical of a computer-mediated learning environment, R-WISE's interactive feedback "[provides] superordinate functions of self-appraisal, [gives] knowledge about one's knowledge, and [initiates] self-management of cognitive activity" (Salomon, p. 621).

- At first glance the highly segmented nature of the adaptive advice may seem to promote short and choppy episodes of text processing. However, the embedded cueing more accurately represents the "contingency management" process of text processing characteristic of the expert. Additionally, these sprint-like activities facilitate modifying or abandoning a strategy, if necessary. And the opportunistic nature of the prompting keeps any single strategy from expanding into a workbook activity, such as the many check lists, acronymic formulas, and visual templates that seem to become ends rather than means in traditional classroom instruction.

REFERENCES

Armbruster, B. B., & Anderson, T. H. (1982). Ideamapping: The technique and its use in the classroom, or simulating the "ups" and "downs" of reading comprehension. (Tech. Rep. No. 36). Urbana: University of Illinois, Center for the Study of Reading.

Armstrong, J. O., & Armbruster, B. B. (1991). Making frames for learning from informational text. (Tech. Rep. No. 542). Urbana: University of Illinois, Center for the Study of Reading.

Bretzing, B. B., & Kulhavy, R. W. (1979). Note taking and depth of processing. Contemporary Educational Psychology, 4,145-153.

Bretzing, B. B., & Kulhavy, R. W. (1981). Note-taking and passage style. Journal of Educational Psychology, 73, 242-250.

Britton, B. K., Glynn, S. M., & Smith, J. W. (1985). Cognitive demands of processing expository text: A cognitive workbench model. In B. K. Britton and J. B. Black (Eds.), Understanding Expository Text: A Theoretical and Practical Handbook for Analyzing Explanatory Text. Hillsdale, NJ: Lawrence Erlbaum Associates, pp. 227-248.

Clarke, J. H. (1991). Using visual organizers to focus on thinking. Journal of Reading, 34(7), 526-534.

Flavell, J. H. (1987). Speculations about the nature and development of metacognition. In F. E. Weinert, & R.H. Kluwe (Eds.), Metacognition, Motivation, and Understanding. Hillsdale, NJ: Lawrence Erlbaum, pp. 21-29.

Garner, R. (1987). Metacognition and Reading Comprehension. Norwood, NJ: Ablex.

Jones, B. F., Tinzmann, M. B., Friedman, L. B., & Walker, B.B. (1987). Teaching Thinking Skills: English/ Language Arts. Washington, DC: National Education Association.

Jones, B. F., Pierce, J., & Hunter, B. (1989). Teaching students to construct graphic representations. Educational Leadership, 46(4), 20-25.

Palincsar, A. S., & Brown, A. L. (1983). Reciprocal teaching of comprehension-monitoring activities (Tech. Rep. No 269). Urbana: University of Illinois, Center for the Study of Reading.

Palincsar, A. S., & Brown, A. L. (1985). Reciprocal teaching: Activities to promote 'reading with your mind.'" In T. L. Harris and I. J. Cooper (Eds.), Reading, Thinking and Concept Development: Strategies for the Classroom. New York: The College Board, pp. 147-160.

Paris, S. G., Cross, D. R., & Lipson, M.Y. (1984). Informed strategies for learning: A program to improve children's reading awareness and comprehension. Journal of Educational Psychology, 76, 1239-52.

Salomon, G. (1988). AI in reverse: Computer tools that turn cognitive. Journal of Educational Computing Research, 4(2), 123-139.

Salomon, G., Globerson, T., & Guterman, E. (1989). The computer as a zone of proximal development: Internalizing reading-related metacognitions from a reading partner. Journal of Educational Psychology, 81(4), 620-627.

Salomon, G., Perkins, D. N., & Globerson, T. (1991). Partners in cognition: Extending human intelligence with intelligent technologies, Educational Researcher, 20(3), 2-9.

Scardamalia, M., Bereiter, C., McLean, R. S., Swallow, J., & Woodruff, E. (1989). Computer-supported intentional learning environments. Journal of Educational Computing Research, 5(1), 51-68.

Tierney, R. J., & Cunningham, J. W. (1984). Research on teaching reading comprehension. In P. D. Pearson (Ed.), Handbook of Reading Research. New York: Longman, pp. 609-655.

Vygotsky, L. S. (1978). Mind in Society: The Development of Higher Psychological Processes. Cambridge, MA: Harvard University Press.

Weinert, F. E., & Kluwe, R. H. (Eds.). (1987). Metacognition, Motivation, and Understanding. Hillsdale, NJ: Lawrence Erlbaum.

Zellermayer, M., Salomon, G., Globerson, T., & Givon, H. (1991). Enhancing writing-related metacognitions through a computerized writing partner. American Educational Research Journal. 28(2), 373-391.