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Interacting with information: Constructing personal knowledge using written text

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INTERACTING WITH INFORMATION:

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USING WRITTEN TEXT

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REMEMBERING

Beloved mother,
Jane Mannolini Vickary Gray

Cherished aunt,
Mary Catherine Mannolini Dopp

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ABSTRACT

This dissertation explores one aspect of solving information problems: the problem solver's transformation of information into personal knowledge. The primary goal of this work is to move toward describing this information problem solving interaction.

Verbal and action protocols provide the data to describe the activity of personal knowledge construction as executed in the context of a student using public written literature to develop a short written text in response to an externally generated information problem. The constant comparative method of data analysis is used to uncover the categories and transformation operators that comprise the activity. A model that depicts both events and operations is presented using the framework of problem solving and schema theories.

Interacting with information is placed within its encompassing environment of information problems and information problem solving. Using the simultaneous verbal reports and the action reports of the participants, the structures and operators of the problem solvers are identified and described in a frame model with three major branches. Two of the three branches represent the problem solvers' knowledge structures relating to the available information and to the problem solver's personal knowledge base. The structures in these branches were developed to show the various aspects and types of a structure that occurred in the data. The third branch represents operators which are used to bring about changes to the structures. Eleven operators were developed and eighteen knowledge structures which were related either

to the information made available in the documents or to the problem solver's previous or developing knowledge base about the problem.

The interaction of the branches is demonstrated in three extended examples drawn from the data. The interactions which were found in the verbal and action reports are discussed and are used to demonstrate the model. The interactions, depicted graphically in a display grid, show the available information the problem solvers used, the behaviors that implemented changes, and the kinds of transformations that were made.

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OVERVIEW

This dissertation explores one crucial aspect of solving information problems: the problem solver's transformation of information into personal knowledge. The primary goal of this work is to describe and characterize this information problem solving interaction.

Verbal and action protocols provide the data to describe the activity of personal knowledge construction as executed in the context of a student using public written literature to develop a short written text. The constant comparative method of data analysis is used to uncover the categories and transformation operators that comprise the activity. A model that depicts both events and operations is presented using the framework of problem solving and schema theories.

In this chapter, interacting with information is placed within its encompassing environment of information problems and information problem solving. In Chapter Two, related research from education, linguistics and cognitive psychology is examined to delineate what is known about interacting with information, or constructing personal knowledge from text-based information. The focus of Chapter Three is to describe the study used to explore these interactions. The model that results from analyses of verbal and action protocols is reported in Chapter Four and Chapter Five concludes with a discussion of significance and future work.

UNDERPINNINGS

This study rests on a framework of philosophical stances that influenced methodological choices. The purpose of this section is to present this foundation.

A major decision for researchers in information studies is their view of information and the role of the individual in an information system. The concepts of information and the user role are foundational philosophical choices which inform and modulate information study decisions on research questions, designated variables, data collection and analysis techniques, and presentation of findings. Currently within information science there are two positions that are evident.

Dervin and Nilan (1986) articulate a "tension" between information science research and practice that is related to the conceptual changes that are occurring. (p. 5) They propose seven categories of comparison in their overview of the underlying premises and assumptions of what are termed the traditional and alternative paradigms. Each is described as an intersection of the seven categories, where each typically occupies basically opposite points on the category continua. Table 1.1 briefly presents paradigm positions on these characteristics.

The traditional paradigm represents the user as a passive recipient of objectively producible information, or to use Dervin's well-known metaphor, a bucket into which a brick of information is deposited. (Dervin and Nilan, 1986, pp. 13-16)

By contrast, the alternative paradigm represents the user as an active constructor of subjectively and situationally bound knowledge, or in an adaptation of Dervin's metaphor, as the potter working clay. (Dervin and Nilan, 1986, pp. 13-16)

Table 1.1.
Relative Positions of Traditional and Alternative Paradigms for Selected Characteristics

Characteristic	**Traditional**	**Alternative**
Nature of Information	Objective	Subjective
Nature of User	Mechanistic, passive	Constructivist, active
Nature of Situationality	Between situations	Within situations
View of Experiences	Atomistic	Wholistic
Focus of Indicators	External behavior	Internal cognitions
Bias of Individuality	Chaotic	Systematic
Nature of Research	Quantitative	Qualitative

This study employs the alternative view of information and user. In brief, the user creates his or her personal knowledge from public information. The discrimination between information and knowledge essentially encapsulates the distinction between an objective or a subjective view of the world. The term information is used to refer to data that has been organized by someone besides the individual using the compilation. It represents an objective version of accumulated world learning. Knowledge has been chosen as the term to represent data that has been personally organized by the individual holding it. It represents a subjective view that envisions reality as shaped by human subjectivity.

These definitions accent the crucial differentiating factor for information and knowledge, which is the identity of the organizer or creator of the product. If knowledge is that which is personal to an individual, and not that which is found in public sources, then it follows that it is the individual who must construct this knowledge. Making sense, the activity of creating personal knowledge, is achieved by individuals situated in an information problem and pursuing a solution. Individuals make sense of the world by actively involving themselves in the generation of that sense. One's view of the world is created by the application of personal effort and attention, producing new knowledge, or changing or deleting currently held knowledge. The building material for this process in instances of information problems is information. "Making it your own" is the key to transforming information to knowledge. It is this key transformation that occupies the center stage in information problem solving.

FRAMEWORK

The overarching frame of the study is that of human problem solving. The casting of the study topic as an information problem and the resulting conceptualization of it in the problem solving constructs of problem space and transformation are direct mappings from problem solving theory, most particularly that enunciated by Newell and Simon (1972). In addition, research on the structure of problems is adapted to information problems. A brief overview of information problems within this theory is followed by discussion of the structure of problems and of Newell and Simon's problem solving theory itself.

Preview

An information need creates an information problem which individuals try to solve. Because knowledge is not an object that can be delivered, problem solvers must construct it to meet their perceived information need. To construct solutions, problem solvers begin with an initial state of knowledge and construct another state through the application of appropriate information transformation operators. This transformation is done within the boundaries of the information problem, which includes topic content and the personal situation of the problem solver. Solvers work toward a solution by iterative application of operators. The transformations reflect the interaction of the components of the information problem and the topic content and personal situation or context of the solver. The solution is personally acceptable to the individual solver as the answer to a personally perceived and understood need. Because knowledge reflects the information problem which is personal to the individual, solutions differ for each individual.

Information Problems

The study concentrates on interacting with information. It is obvious, however, that the interaction is conducted within the larger context of information problem solving. A review of this encompassing problem solving framework sets the stage for the research issue of interacting with information and provides an opportunity to establish the scenario chosen as the vehicle for study.

Information Vignettes

Consider these everyday situations to which one could apply the term "information problem":

Edwina Executive, the proprietor of her own firm, is perusing the Wall Street Journal while on the train enroute to her office. Her attention is caught by an article about affordable dental plans for employees. She reads it and notes that it seems to apply to firms like hers. She begins thinking about the usefulness of the plan in her business and wishes she knew more about it.

Sammy Student is preparing a paper for one of his courses at the local university. A search done for him by the reference librarian has resulted in several documents that are topically related to his paper. After retrieving these sources from the library stacks, he begins to use them as sources in creating his paper.

Mike Mechanic, employed at Ben's Auto Repairs, is trying to fix the faulty carburetor on a new model car. He has fixed other carburetors, and even ones displaying the same symptoms, but he has not worked on this model before. He gets the manual that the company gives to its service representatives and turns to the section that deals with carburetors. He finds a diagram and a number of tips on how to fix carburetors which show certain malfunction symptoms. None of the malfunctions mentioned are an exact match for the symptoms of the problem he is working on. He reads the paragraphs that seem to have something to say about his problem, and comes up with a combination of suggestions to try.

Molly Mother wants to bake a special cake for her son's birthday. She searches through the cook book and finds a recipe for a cake that sounds delicious. She makes a list of the ingredients that she needs and goes off to the store to buy them.

In all walks of life, within all elements of their lives, people encounter situations in which they are stymied by a lack of knowledge. Chen and Hernon reported in 1981 that during interviews with 2400 people in the six state New England area, there were approximately 3500 work and non-work related situations in which a person had to make a decision, answer a question, solve a problem, or understand something--in short, "situations where a person stopped and thought about what he/she was going to do." (p. 122) Of the reported situations, all of which occurred within one month of the interview, slightly more were likely to be non-work related than work related (55% to 45%). Although, as Chen and Hernon pointed out, situations and information needs are not the same, it is suggested that "information needs arise naturally within the context of individual situations" (p. 136). These few vignettes support this suggestion.

General Aspects

These vignettes are useful in illustrating several general aspects of information problems. First, all the pieces involve a lack of knowledge, which is recognized as a frequent and common condition for humans. It is clear that a knowledge gap exists in each situation. Each of the individuals is trying to accomplish something, and each finds that he or she lacks some knowledge of value in the situation. Note the use of the term "knowledge." In this study, knowledge connotes personally organized and held data or information, following the definition used by Debons et al. (1988, p. 8) Knowledge is understanding created by personal intellectual effort and action.

Secondly, not only is this lack of knowledge perceived by the individual but also it is recognized as the crucial factor in the stymie. That is, each of the protagonists appreciates that attaining personal knowledge will remove the knowledge gap and, further, that removing the gap provides the means to move toward a desired goal. It is this dual perception of the gap and the means of remediation that produces the environment in which action becomes possible.

A third feature exhibited by the examples is that each occurs as a distinct, unique situation, with its own surround. That is, each of the individuals is situated in a particular time and place, and each embodies his or her own personal life experiences, beliefs and aspirations. The situation encompasses those elements that particularize the situation, both between individuals and within the same individual at different times.

What Are Problems?

These three aspects of the vignettes appear to fit definitions and intuitions about problems. But, what is a problem? A clearer understanding of "problem" is needed in order to characterize the situations as problems.

Webster's Ninth New Collegiate Dictionary defines problem as "a question raised for inquiry, consideration, or solution; an intricate unsettled question; a source of perplexity, distress or vexation." Roget's International Thesaurus, Fourth Edition lists these concepts as related to problem: annoyance, difficulty, fault, perplexity, puzzle, question and topic. These entry concepts lead to synonyms ranging from slang phrases such as "pain in the neck," "mind boggler," and "hornet's nest" to more conventional terms such as "issue," "mystery," and "bafflement."

Reitman wrote in 1965, "Although problem solving has been studied for many years, there seems curiously enough to be no generally accepted definition of the concept of a problem itself." (p. 125) The diversity of application of the term reflects the ubiquity of ambivalent situations in life. 'Problem' is used to refer to everything from manipulation of mathematical formulae to creation of art objects. As with many concepts it is difficult to specify the exact commonality among its disparate examples. An Aristotelian "necessary and sufficient" definition is not easily found from the examples of problems that are encountered. That is, there is no one aggregation of conditions or features which all problems share and which determine membership in the set of problems.

However, problem as a category does seem to be realistically described in a Wittgensteinian "family resemblance" sense. By family resemblance is meant that although individual instances of problems do not all share the same characteristic or feature, each seems to have some varying shared element with other members in the family of problems. For example, biologically related members of a family may share similar facial features, such as a prominent nose or the shape of an ear lobe. It is likely that members of this family each have some of the shared features but not all of them. And it is likely also that different members of the family share the same feature with others, but that no two share the exact same features with all other members. Sister may share the ear lobes with Mom and Brother, while Brother also shares the nose with Dad but not Sister. An observer is frequently able to remark that siblings "look alike," even though there are numerous differences as well as the shared features.

For Reitman (1965), these shared elements are expressed simply in this statement: ". . . , we say a system has a problem when it has or has been given a description of something but does not yet have anything that satisfies the description" (p. 126). This brief statement contains the elements also found in Newell and Simon's (1972) concept of a problem: "A person is confronted with a problem when he wants something and does not know immediately what series of actions he can perform to get it" (p. 72). These conceptualizations both depict a future relation between the objects (the "something) and actions (the "satisfies" and "perform"): they are joined by the underlying family relation of wanting but not yet having. As pointed out by Thomas (1989), "It should be clear, then, that what constitutes a "problem" is not a "thing" but a relationship involving the system (e.g., a person, a corporation, a computer program, a team), the state of perceived reality and the state of desired reality" (p. 317). Newell and Simon further note that the objects can be tangible or abstract, specific or general, physical or symbolic; the actions physical, perceptual or mental. Thus, membership in the family of problems is open to many different life situations. In this study, problem is used in this sense of a relationship between a person, a desired state and a current state. More specifically, a problem is not having something in a current state that is wanted or needed to create a desired state.

The Structure of Problems

A refinement of problems yields a categorization of them by structure. McCarthy's (1956) notion of a well-defined problem led to Reitman's (1964) and Simon's (1973) work on ill-defined or ill-structured problems. These types are commonly considered the two anchors of a continuum rather than a dichotomous separation of the problem family.

Based on an examination of selected samples from the domain of transformation or creation problems, Reitman (1964) described six problem types which varied in completeness of specification of the components. (pp. 284-288) A transformation problem is one in which the problem requires mutation of the situation by the application of a sequence of operations. Figure 1.1, based on Reitman's typology, illustrates this variation within the problem family. Each axis of the cube represents one facet of the definition of a problem: the X axis graphs thoroughness of the specification of the initial state; Y axis, the completeness of specification of the final or goal state; and Z axis, the ensemble of known and appropriate operators. All three axes use the same scale: specified (S) which indicates that conditions and/or operators are known and declared; qualified (Q) which means that some conditions may be known but some are not; and unspecified (U) which indicates a lack of knowledge of the conditions of the state or the set of operators.

The lower left corner of the cube, labelled with a W for well-structured, represents the location of problems having the most structure. The upper right, identified with a C for complex, locates those problems showing the least structure. As initial states, final states and state change operators move from specified to qualified to unspecified, problems exhibit a deterioration in available knowledge and an increase in vagueness and abstraction.

The examples used by Reitman of each problem type are presented as a short cut to understanding the characteristics of problems that he considered in identifying different types. For convenience, the examples are shown in order by structure. Order is based on a simple scheme which assigns a weight to each of the three points on the scale (1 for S, .5 for Q, and 0 for U) and sums a type's individual weights to determine its place on the structure continuum.

Types 3 and 4 both display the most structure of the six types. Type 3 is exemplified by the concoction of the recipe for Chicken Marengo by Napoleon's chef--he had to create a celebratory meal with the ingredients at hand (initial state = S), but he did not know exactly what the outcome would be (final state = Q). He did know various cooking methods (operators = S). Type 4 is illustrated with a task to "take a vehicle and a power source and link them in such a way that the resulting combination is a vehicle which moves itself." In this case, the solver has a reasonably clear idea of what he or she is starting with (initial state = S), and what

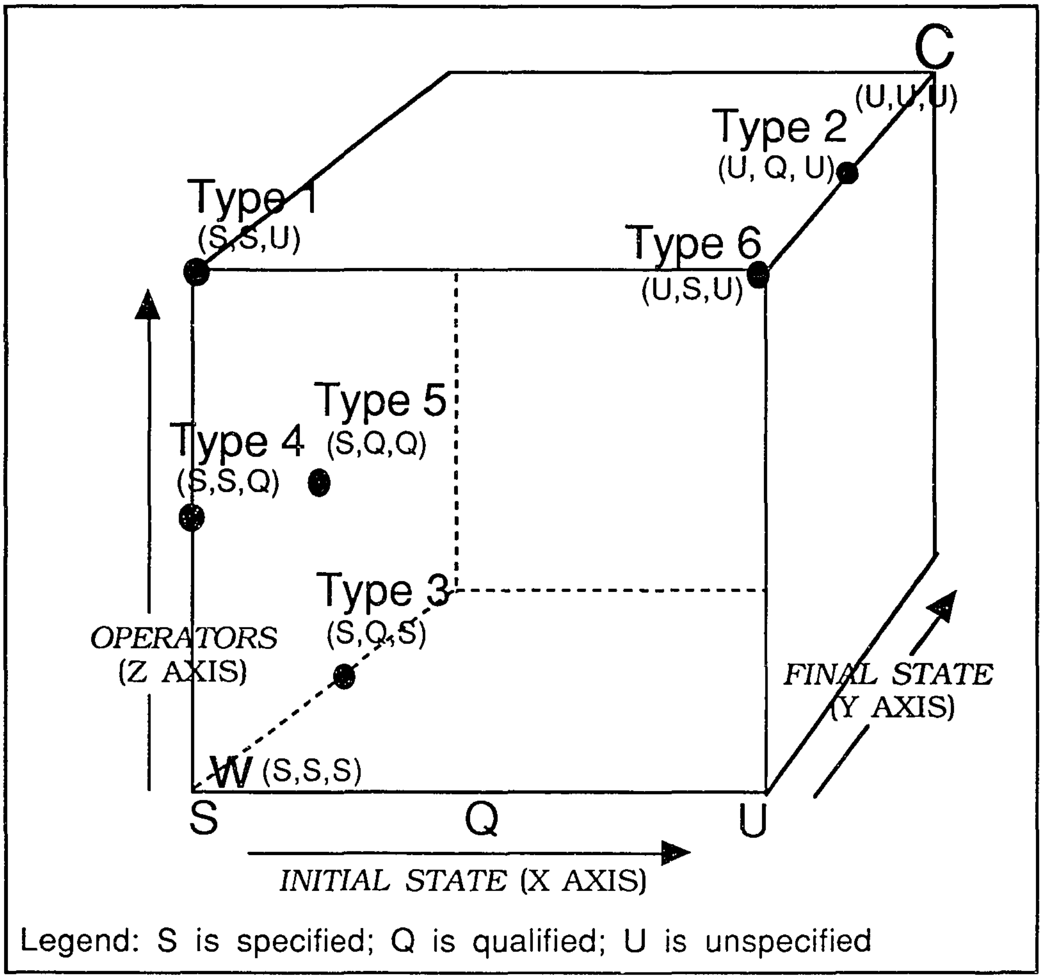

Figure 1.1. Problem type by degree of structure

the final product is supposed to do (final state = S). The solver does not know precisely what the "link" is; however, he or she does know that it must do a specific function (operators = Q).

Types 3 and 4 share the qualities of being less defined in only one dimension and having fairly complete knowledge of each of the dimensions. Type 5 problems, on the other hand, offer situations in which two dimensions are less defined, although there is some knowledge available for all dimensions. The example used is that of redesigning a stereo center, starting with a current product (initial state = S) and producing a result (final state = Q) that could be produced without radical retooling (operators = Q). Operator knowledge is constrained by the requirement that the final product should use as much as possible of the available production methods. This type of knowledge is usually called constraints on the operators as opposed to knowledge of the actual operators. Even so, it seems reasonable to say that the solver has some knowledge of operators because there is some basis for selecting or discarding an operator.

Problems of Type 1 share with Types 3 and 4 the quality of being poorly defined in only one dimension, but the degree of uncertainty on that one dimension is much higher. Type 1 problems are illustrated by the improbable task of making a silk purse from a sow's ear. In this case, knowledge of the starting position is clear (initial state = S), and desired configuration of the goal is also clear (final state = S). But, the operators to move from here to there are completely unknown (operators = U). This example seems to identify a problem without a possible solution, because no operators are known from which to build a sequence of necessary transformations. Operators for destroying sow's ears are known, as are operators for creating silk purses. However, the two sets of operators do not overlap in any known fashion; so, no matter how many transformations are made, one does not progress from sow's ears to silk purses.

Type 6 and Type 1 problems differ in only one respect. Whereas Type 1 problems are completely specified at the initial state, Type 6 problems are almost completely unspecified. Type 6 problems are demonstrated by two examples. One is the scientist who wants to account for a curious phenomenon just observed; the other is the apprehended thief searching for an alibi. In both cases, the events preceding the current condition are unknown, or in the case of the thief, unacceptable (initial state = U), whereas the final state is well-known (final state = S). The operators dimension is unspecified, as it calls for discerning a reasonable set of transformations to connect the goal to the initial state, either to explain the occurrence and characteristics of the phenomenon or to provide an innocent rationale for the events leading up to the apprehension (operators = U).

The last type, Type 2, is cast as composing a fugue. In this case, there is no direction given about what one starts with (initial state = U), although there are some expectations of the form of the product, since a fugue is defined within music (final state = Q). The operators which will achieve the product are undeclared, although one would anticipate that appropriate operators would exist (operators = U).

The Structure of Information Problems

The situation of needing and getting information appears to fit the definition about having a problem. If so, where do information problems reside in the problem cube? And, what is the level of complexity of the Sammy Student situation?

Information Problems in General

A review of what is commonly known about information problems follows in the information problem solving section. However, it is possible to classify the level of structure of an information problem in the terms used for problems and indicate its relative standing in terms of structural complexity at this time.

Initial State

On the dimension of knowledge of the initial state, one is tempted to say that information problems are unspecified, that knowledge is practically nil. It is true that there is a consensus that information problems derive from information needs, most commonly depicted as a gap, by definition a void. However, it would be difficult to comprehend how one could be engaged in a goal directed activity such as problem solving if one did not at least recognize the existence of a gap and have some, however minute, grasp of the nature of the information need. Learning for the sake of learning is an accepted endeavor, but is not usually classed as problem solving. Because some level of knowledge exists about the initial state, the information earns a Q or qualified specification for the dimension.

Final State

In terms of the final state, an information problem may be shown to be partially known. Although the exact composition of the final state is not known, some of its aspects are. For example, it is known that it must be "about" a particular topic. This is very little knowledge perhaps, but it is enough to assist in an evaluation of whether the problem is solved. In addition, in some cases, the form for an acceptable answer is specified --

a written answer, an oral answer. This state is also given a Q or qualified specification rating.

Operators

Knowledge of operators also seems to be partially available for an information problem solver. The general processes of solving a problem are available in advance. For example, one can acknowledge at least that reading (or some form of acquiring access to the information) will be necessary. The choice of which specific operators will be used at a particular time for a particular interaction is not identifiable in advance. Various problem solvers may use different operators but still produce an acceptable answer. Because the general group of operators is known, while the specific ones to be exercised are not, the specification of operators is also considered Q, or qualified (operators = Q).

As displayed in Figure 1.2, information problems sit in the center of the cube, with a Q value on each axis. In terms of complexity, they are moderate in value.

As Pines (1985) points out, ". . ., complexity arises out of various elements related in various ways or, to put it another way, in order to exhibit complexity, elements and relations must vary" (p. 102). Relations do vary in the information problem, although not so much that a problem is intractable.

Sammy Student Information Problems

The Sammy Student scenario is a particular instance of an information problem. A brief look at its characteristics will show that it too is moderately complex due to its particular situational factors.

The Sammy Student scenario shares with the general information problem a partially known beginning state (initial state = Q) by virtue of two facts. First, the topic is posed as a question to the subject, thus

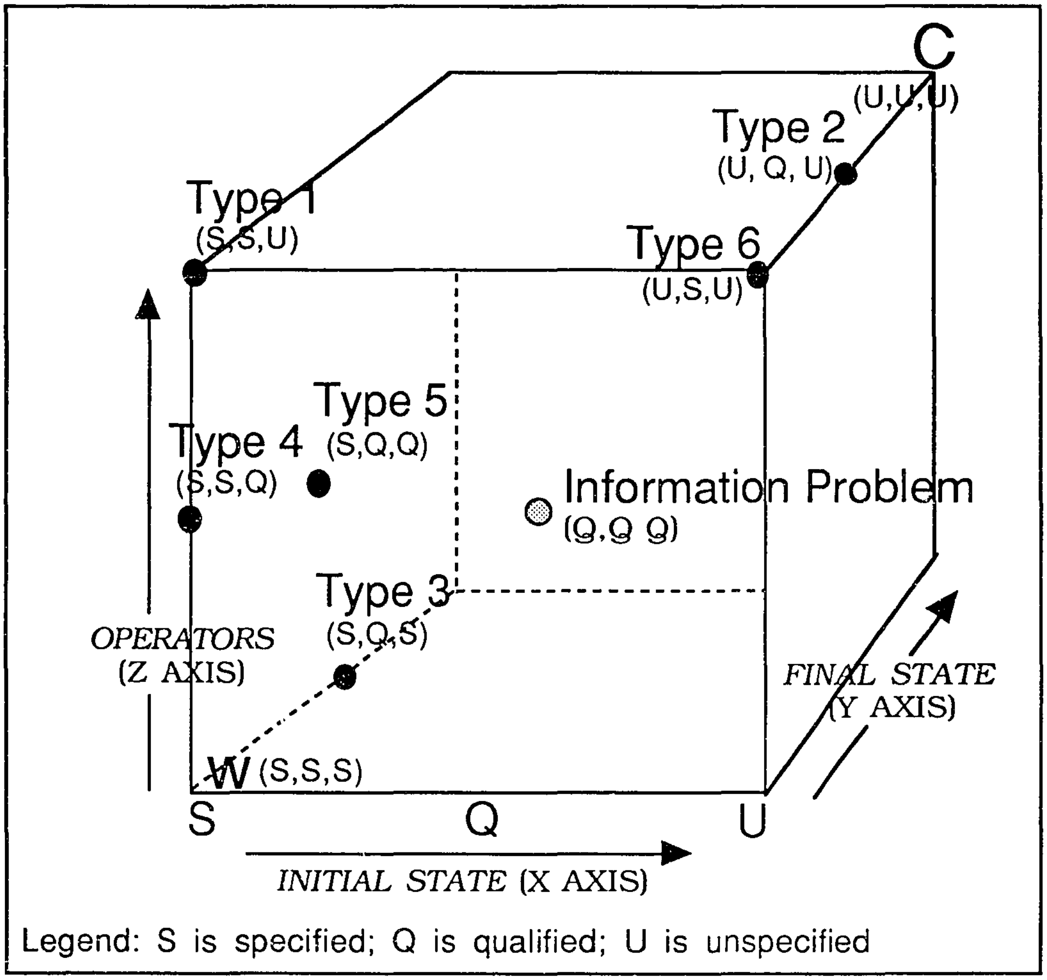

Figure 1.2. Problem cube showing location of information problems

identifying an area of knowledge that is relevant. At the same time, the actual knowledge gap of a subject is unknown and is highly likely to vary among subjects.

The Sammy Student scenario shares a qualified final state status (final state = Q) both by virtue of having a designated topic (although unnamed in the vignette) and by having the form of the result specified in advance. These provide a minimum community consensus about the existence and form of a suitable answer.

Sammy Student scenario is one which has been undertaken by students many times in their school careers. Because of this, subjects have some knowledge of appropriate operators; thus, the status of specification of its operators is at the qualified level also. That is, the general process of writing a paper, including the development of a topic, the searching for public information sources, the use of the sources to gain some personal knowledge about the topic, and the writing of the final product, usually a paper, have been well documented by Kuhlthau in her model of the library search process. (Kuhlthau, 1983) The specifics of a problem solver working with individual retrieved information sources, wherein one would find the use of operators, are not available in this model but are addressed in related work to be discussed in Chapter Two.

Information Problem Solving

Having examined the structure of problems, the next step is to consider the process of solving problems. In addition to possessing features of a problem, the vignettes also exhibit a process that produces a solution. That is, comparison of what is known with what is desired culminates in recognition of a knowledge gap and gives rise to a perceived information need. Recognition of the need for information and motivation to resolve it initiated the holders' actions to close the gap. These actions included gathering and seeking information sources which became the raw material of knowledge construction. Then information from outside sources was integrated to construct personal knowledge. This knowledge closed the original gap, and moved the individual closer to his or her desired state.

Note that it is a knowledge gap that raises a need for information. Information is organized data of which one is aware, but without the cachet of personal organization that knowledge holds. (Debons et al., 1988, p. 8) Information becomes the raw data of personal knowledge construction. It is the availability and use of information that fuels the individual's construction of knowledge.

Information problem solving resembles a set of nested dolls. Innermost is the recognition of the lack of personal knowledge and of the gulf it represents between current position and desired position, characterized as an information need. Surrounding the information need is an information problem which encompasses not only the information need but also the surrounding personal situation and environment in which the need exists. Outermost is information problem solving which may occur given that the person is motivated to resolve the problem. It is the process of pursuing a solution that is the active element in problem solving. An information problem is a transformation problem, that is one in which there ". . . is an initial situation and a goal and a set of operations that produce changes in situations" (Greeno, 1978, p. 241). Transformation problems are usefully examined using Newell and Simon's theory of human problem solving, since transformation problems were the basis of the theory.

What Is Problem Solving?

The study of human problem solving has a long history which has culminated in modern times in a theory based on the information processing approach. Ably presented by Newell and Simon (1972), this theory suggests that problem solving is a search in a problem space for a path of operators that transforms an initial state into a final state, which represents the goal of the search.

The theory may be summarized as follows. The problem solver's representation of the features of the problem at a specific time is identified as a state. The problem space is a collection of internal representations of the problem that are constructed by the solver. It is the solver's personal subset of the task environment, which is a representation of the problem in as complete and neutral a way as possible, including states, operators, and constraints. All states following the initial state are brought about by the use of operators that change an element of the incoming state to create a new and different state. The choice of operator depends on the solver's understanding of the current state, the effect of an operator, and the desired final state. Search is moving through the nodes of representation of the problem space, accessing and entering different states of knowledge through the application of chosen operators. A sequence of applied operators comprises a path; it is this constructed path that comprises the solution.

States and Operators

States and operators are structural building blocks of the theory. Initial states and final states, as we saw in the discussion of problems, are of particular interest in specifying the structure of the problem. It is content that distinguishes one state from another. An operator generally specifies a discrete change to the token value for a single component of the state, a specific type slot.

The Problem Space

The problem space is essential to understanding the concept of search. Because the problem space is used to describe not only the overt actual behaviors but also the set of possible behaviors and the behaviors considered but not overtly possible, it amounts to constructing a subject's representation of the task environment. As Newell and Simon (1972) describe it,

> The subject in an experiment is presented with a set of instructions and a sequence of stimuli. He must encode these problem components--defining goals, rules and other aspects of the situation--in some kind of space that represents the initial situation to him, the desired goal situation, various intermediate states, imagined or experienced, as well as any concepts he uses to describe these situations to himself. (p. 59)

In constructing a problem space, Newell and Simon concentrate on the stimulus and feedback rules that a subject might use. It is the behavior of the subject in regards to the stimulus, including the feedback the subject receives from the environment as a result of his behavior in the problem situation, that comprises the problem space, since the subject does not know the real problem but only the stimuli presented. Pragmatically, an objective representation of the task environment for a problem becomes all those representations that are actually used by subjects in that problem situation. (p. 64) Further, according to Newell and Simon, "The problem space is defined in relation to task goals, and the representations have been restricted to aspects of the total environment that were task-relevant" (p. 71). It is within this problem space that a solution is constructed through searching.

Search, Path and Solution

In discussing search, Newell and Simon differentiate between state language, which consists of "Symbols that designate expressions, elements of expressions, characteristics of expressions, or differences between expressions . . ." and process language, which consists of "Symbols that designate operators for transforming expressions, sequences of operators, or characteristics of operators . . . " (pp. 76-77). The internal representation is described in state language whereas the transformations required to change a state are described in process language. The problem is solved by the appropriate application of process operators to symbol states. Search is the process of devising a path through the possible states such that the path realizes the desired goal state. It is worth noting that the structure of the search space is not the exclusive result of the task environment alone, but also depends on the problem space and program which is employed by the solver. (p. 77) This introduces the possibility that nonrealizable states are considered, which may have been generated by the use of operators that do not meet all the conditions of constraint. The search takes place in the internal problem space, not in the external task environment, thus allowing imaginable as well as realizable states and operators. But, as Newell (1980) points out, the solution is constrained by the task environment and will consist of a legitimate path of applied operators producing a permitted state. (p. 697) In common terms, solutions may be the attained final state, or the path of operators that produce the final state, or the sequence of intermediate states.

Information Problem Solving Framework

Figure 1.3 graphically illustrates information problem solving. It shows the interrelatedness of information need, gathering and seeking information, constructing knowledge and using the constructed knowledge. These process components are depicted within the situation which surrounds and is part of an information problem.

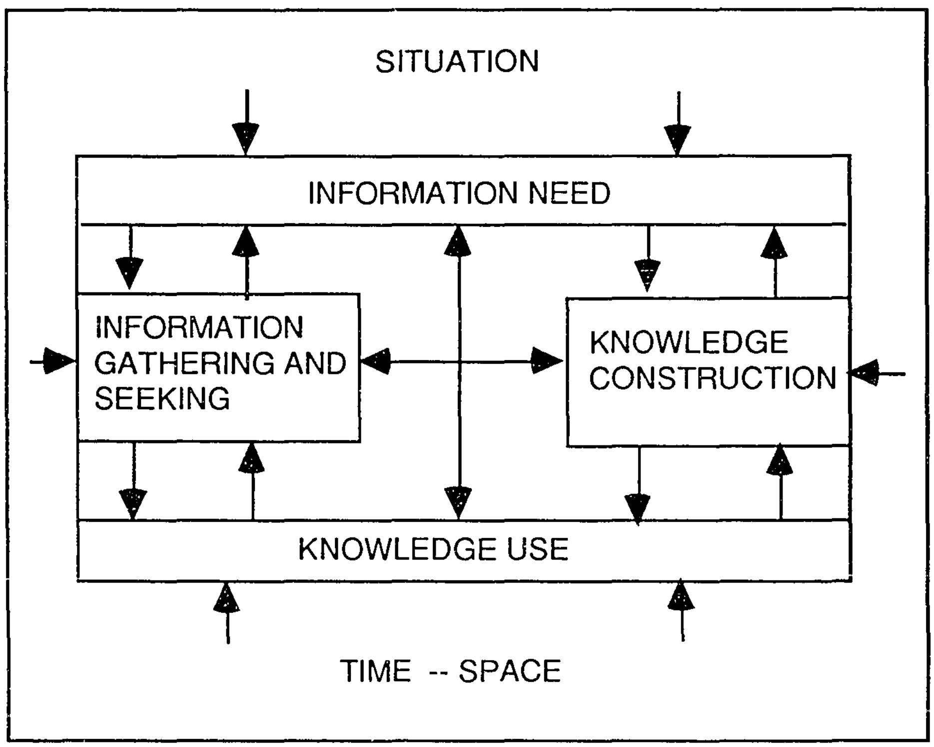

Figure 1.3. Information problem solving components and interactions

Problem solving is represented by the arrows that show various interactions of components and situation.

Although this study is focused on the exploration of knowledge construction within this relationship of processes, each of the interacting components contributes to that knowledge construction effort. These components are themselves complex activities. Their interaction is an essential ingredient in the definition and solution of an information problem.

Information Problem Solving Situation

Since the situation surrounds the other components, it is appropriate to start with a look at what role it plays in the overall process. It is germane to recall Heraclitus' remark: "All is flux, nothing stays still." It is common to remark that individuals exist in time and space continua that are not static but ever changing and to acknowledge that unique temporal and spatial qualifications permeate each of their moments.

Identifying Particular Situational Features

It is another matter altogether to define or even describe this "ever changing" context. Most commonly one finds recognition of the existence of situational or environmental features that are in some manner involved in an action or event without precise identification of what these features are. For example, Wersig and Windel (1985) describe the human being at a certain time as influenced by four factors:

1. Present situation.
2. Past states of the organism (personal history).
3. System of preferences (values, opinions, attitudes, etc.).

4. Set of potentials (cognitive, affective, aesthetic, etc.). (p. 15)

It is certain that situations vary infinitely as to particulars, thus producing a unique quality for each. Situational features vary not only in whether they occur but also in the details of an occurrence. That is, similar experiences may be similar by reason of similar situational features, but it is assured also that there will be variations in some of the specific details of a feature. But, a notable difference between experiences is most likely to be whether a particular situational feature even occurs for that experience. Situational uniqueness, then, depends on differences and similarities at both the level of occurrence or the level of what (exactly) occurred. In brief, one may have type as well as token variations.

Several researchers have considered situation as a primary component of personal action. Three useful portrayals are those from Suchman, Dervin and Sperber and Wilson.

Suchman's Situated Actions

Suchman (1987) introduced the term 'situated action' to account for "the view that every course of action depends in essential ways upon its material and social circumstances" (p. 50). She goes on to characterize situated action with two basic premises:

> . . . first, that what traditional behavioral sciences take to be cognitive phenomena have an essential relationship to a publicly available, collaboratively organized world of artifacts and actions, and secondly, that the significance of artifacts and actions, and the methods by which their significance is conveyed, have an essential relationship to their particular, concrete circumstances. (p. 50)

In discussing the ramifications of such a view, Suchman proposes that *in situ* actions are those that are the actual acts; represented actions, such a plans or reports of actions, derive from these through the individual's objectification of a proposed or past action. During normally proceeding actions, the actor experiences smooth and transparent operation of the procedure. On certain occasions, such as during breakdown, required parts that are involved in a particular activity become unavailable, broken or not ready for use. At this time, an individual engages in problem solving to repair the disturbance, developing a repair procedure. Situated action is not made explicit by rules or procedures but becomes accountable by rules when the rules are explicated in problem solving. Action, which is not rule based or procedural, becomes so upon special effort, such as planning or reporting, of the individual. An interest of prime importance becomes the methodology of " . . . members of the society in coming to know, and making sense out of, the everyday world of talk and action" (p. 57). Evidence of intent is not reducible to logical sets of necessary and sufficient conditions; a behavior must be interpreted in light of its context, which itself presents no algorithm for conjoining contextual particulars to behavior. As one searches for uniformities that underlie unique appearances, actions are interpreted as evidence of underlying plans or events, which in turn fill in the sense of the actions. But, regardless of the typifications of circumstance and behavior that are developed by a society,

> . . . no action can fully provide for its own interpretation in any given instance. Instead, every instance of meaningful action must be accounted for separately, with respect to

> specific, local, contingent determinants of significance. (p. 67)

It is these "specific, local, contingent determinants of significance" that one needs to identify in order to characterize accurately an instance of situated action. Information problem solving as an instance of situated action also would benefit from recognition of local contingencies.

Dervin's Arsenal of Situation Movement States

Whereas Suchman addresses situations in the context of interaction with objects within a particular circumstance, Dervin addresses the cognitive circumstances of situations and characterizes behavior as ways to move within a situation.

Dervin (1983) identifies 11 measures which show the different ways in which respondents see situations that predict information use. (p. 60) All of these are features which were identified as emanating from the individual information seeker (or problem solver in this study). The first measure, labeled situation movement state, received the most attention. Refined into 11 sub-states, it was a measure for "ways in which a person sees his/her movement through time-space being blocked" (p. 61). Examples of these situation movement states are conditions such as "decision," in which an individual is at a point where a choice between two or more paths lies ahead; "barrier," or knowing where one wishes to go but being blocked by someone or something; and "moving," in which one sees oneself as proceeding unblocked in any way and without the need to observe (where observing is watching without being concerned with movement). (p. 61) These are all dynamic features which may be captured only in the moment. Dervin et al. (1982) considered this a "time-space bound situational measure" which is contrasted with recurring across time-space features which characterize an individual in different situations occurring at different times and *a priori* situational features which characterize an individual before interaction with information. (p. 809-810)

These state features are complemented by ten additional measures that describe a situation: situation clarity, situation embeddedness, social embeddedness, situation importance, past experience, ability to deal with, power to change, openness to communication, status in situation, and distance into situation. Again, each of these features is reported from the viewpoint of the information seeker, and each has a dynamic essence which characterizes this approach to situational features.

Sperber and Wilson's Contextualized Relevance

Situation is perceivable context. It is in this sense that Sperber and Wilson address situation at the cognitive level rather than the activity level.

Sperber and Wilson (1986) address the issue of how one develops relevance in a conversation. Their theory provides that relevance, by virtue of relying upon cooperation between participants of a communicative act, is contextually situated. If new information modifies or adds to old information already held by a person, it is said that a contextual effect has occurred for that person. In very general terms, they hold that information is ". . . relevant to an individual at a given time if and only if it is relevant in one or more of the contexts accessible to that individual at that time" (Sperber and Wilson, 1986, p. 144).

Harter (1992) adapts Wilson and Sperber's work on relevance in communication to the concept of relevance within information retrieval. He discusses the application of information within the context of "bearing on the matter at hand" (p. 603). Following Sperber and Wilson, ideas are manifest to individuals when they are able to represent them mentally and accept their representations as true or probably true. The set of facts that are manifest to individuals at a particular time compose the cognitive environment for an individual at that time. It is the set of manifest cognitive elements which determine what an individual is capable of perceiving and inferring, although they do not mandate that a given fact will be perceived or inferred. Individuals combine cognitive and physical environments into situations in which they exist, think and act. A necessary condition for perception or inference in the sense of being relevant to the matter at hand is that the fact has contextual effects. Contextual effects derive from the interaction of a manifest fact or assumption with the cognitive environment existing at that time. The interaction has three possible outcomes: creation of new information by the logical deduction of new from the incoming fact or assumption and old knowledge; old knowledge may be erased or overwritten or new information may strengthen old knowledge; and no effect occurs at all. Context is selected by individuals in order to maximize the relevance of new information while at the same time minimizing processing effort. (pp. 604-605)

Situation is one of the least understood components of information problem solving, but one that is increasingly recognized as exerting a prominent influence on the process. It is a specific objective of this study to uncover the components of situation and environment that are present in information problem solving behavior of the subjects.

Information Need

The primary observation about information needs is that they are vague, difficult to express, and malleable.

Sources of Information Needs

An information need is the kernel of an information problem just as knowledge gaps are the essence of information needs. Gaps arise from two sources, giving rise in their turn to information needs. One source credits a need to a lack that has been internally created; the other to a lack created by an externally imposed task. Although they seem to be qualitatively different, one subsumes the other. To solve an externally generated information problem, one must perceive a knowledge gap in order to recognize the information need. Thomas (1989) calls this "problem finding" (p. 327). Formulating the actual knowledge gap is necessary for externally generated information needs just as recognizing them is necessary for internally generated information needs. For example, if a work project includes the task of acquiring information on some topic, the specific knowledge gap that is the center of the information need must be recognized and formulated as part of solving the information problem in which it now occurs.

An advantage seems to lie with the internally created need. Although not consciously available, useful knowledge about the need is assumed to exist in the unconscious in which it developed. A source thus exists for use in succeeding steps because need holders are assumed able to sound this gap as they solve information problems. Since externally posed information tasks become at least partially internalized, both variations are considered to engender information needs.

The Gap Metaphor

The gap metaphor is used in almost all current characterizations of information need. Whether presented as a discontinuity (Carter 1980), as a dissonance (Festinger, 1957), as an anomalous state (Belkin et al, 1982), as a conceptual incongruity (Ford, 1980), or as having something less than needed (Krikelas, 1983 and Horne, 1983), the central core of an information need is seen as a void in the aggregation of the holder's personal knowledge.

In Carter's theory of discontinuity, a need is the notion of a discontinuity or gap. A gap is a normal part of reality arising from Carter's assumption that reality is neither complete nor continuous. Rather, reality is a condition in which all things are unconnected and in constant change. The universe is made up of multiple things or events and is not unified. A discontinuity condition exists between these things, with the result that reality is filled with fundamental and pervasive discontinuities or gaps.

The psychologist Leon Festinger viewed non-fitting relations among cognitive elements as the source of cognitive dissonance. Individuals strive toward consistency within themselves--for internal consistency among the facts, knowledge, opinions, beliefs they hold about themselves, the environment or their behavior. Two elements are dissonant, when, considering these two elements alone, they are opposites of each other. This condition of cognitive dissonance causes an anomaly in one's belief system, giving rise, upon one's perception of it, to a need for resolution.

Belkin et al. (1982) characterized these gaps as anomalous states of knowledge, a "recognized anomaly in the user's state of knowledge concerning some topic or situation . . ." (p. 62). Further, the need holder is, in general, unable to specify precisely a resolution of the anomaly. The attributes of the gap are proposed as a means of achieving specification of potentially useful information.

Ford defines information need as a conceptual incongruity in which the person's cognitive structure is not adequate to a task. Awareness of the incongruity is essential to Ford, who seeks characteristics of ways in which individuals seek and respond to new information in order to ameliorate an incongruity. (Ford, 1980)

Krikelas (1983) conceptualizes need as an event in which "the current state of possessed knowledge is less than that needed to deal with some issue (or problem)" (p. 7) or as recognition of the existence of uncertainty (p. 6). He explicates that the formulation of a need is a compound event that involves "differentiating *when* a need is realized and *how* it is expressed" (p. 8, italics in original). This leads either to immediate needs that produce overt action, termed information seeking or to deferred needs that are delayed in satisfaction, termed information gathering. This differentiation is observed in the information gathering and seeking component that is discussed below.

Horne (1983) operationalizes the gap metaphor as an information need which induces a drive state, called inquiry, which exists when there is insufficient knowledge to cope with voids, uncertainty, or conflict in a knowledge area. The information need is observed in the behavioral act of forming a question and is studied by examining the inquiring process. The entire inquiring process of questioning and answering results in thc subsequent altering of one's state of knowledge pertinent to the need about which one wished 'to know'.

Taylor's Levels of Information Need

For most researchers, the concept of information need is monolithic, with little in the way of parts or pieces. It is usually defined as a preliminary before going on to study the next component in the information problem, information gathering and seeking. For Taylor (1968), however, information need is not monolithic. In his seminal article on question negotiation and information seeking, he identified four stages of perception of information needs: (1) the visceral need, or the unconscious need for information not existing in the remembered experience of the inquirer; (2) the conscious need, or the conscious mental description of an ill-defined area of indecision; (3) the formalized need, or the qualified and rational statement of the question; and (4) the compromised need, or the question recast in anticipation of what the information sources can deliver. (p. 182) Of these four, the first two are most reasonably related to the information need component, whereas the second two are most likely integrated within knowledge construction and situational factors.

Visceral Need. Carter's gap, Festinger's cognitive dissonance, Belkin et al.'s anomalous state of knowledge are most closely related to visceral need. This is the bedrock gap whose bridging or filling is the goal of information problem solving. As the foundational perception of need, visceral need is the knowledge gap but not yet the information need.

Visceral need (the knowledge gap) is most difficult to define and is usually considered to be unarticulated. As Taylor (1968) says,

> It may be only a vague sort of dissatisfaction. It is probably inexpressible in linguistic terms. This need (it really is not a question yet) will change in form, quality, concreteness, and criteria as information is added, as it is influenced by analogy, or as its importance grows with the investigation. (p. 182)

It is unobservable of itself, and must somehow be manifested. Nevertheless, it occupies the key location in Taylor's and others need-question hierarchy. It is the crucial foundation of what becomes the information need. Holding this level of need is what distinguishes the problem solvers from intermediaries or people who are trying to assist in the solution process. Although unable to be fully articulated, it is upon this level of need that judgment of pertinence, development of problem solving constraints and acceptance of the solution ultimately rests.

Conscious Need. While it is the visceral need that is of prime interest, it is the conscious need that is overtly studied. Visceral need which has progressed to some recognition of its existence has become an information need. For researchers interested in studying information problems, whether as information seeking or knowledge construction, the existence of a perceived information need is a necessary condition. The visceral need or the knowledge gap must be operationalized in some manner.

Taylor and Horne both demonstrate that questions are one way to operationalize need. Questions are the overt behavior that indicate the content of a need. It is through the formulation of questions that the visceral need becomes observable. The ability to ask a question, to frame the need in some language, is an important step toward the information problem and its solution.

Characteristics of Information Needs

The information problem vignettes depict the kind of need that Frants and Brush (1988) call a "problem-oriented information need." Problem-oriented information needs have characteristics which are fuzzy. For one, their boundaries are not well defined, and the information need cannot be expressed precisely. For example, for Edwina Executive as she reads about a dental plan in the paper, the information need is just beginning to be recognized. She does not know specifics of the information that will help her, just that more would be helpful. For Sammy Student, who is getting ready to write a paper for class, a need is known in general terms, as a topic, but the specifics of the topic are yet unknown.

A second characteristic of a problem-oriented information need pointed out by Frants and Brush is that receiving pertinent information has the effect of modifying the information need, "expanding" it, so that the question remains for an appreciable time. Note that a problem solver's beneficial interaction with information uncovers new knowledge gaps that continue to alter and shape the originally promulgated information need.

Information Gathering and Seeking

One natural outcome of having an information need is to try to resolve it. (The other is to put it off or just ignore it.) It is the conscious perception of an information need, coupled with motivation to do something about it, that enables information gathering and information seeking.

Information is the basis of concern of many different disciplines. It is central to disparate fields such as artificial intelligence, cognitive science, communication science, computer science, library and information science, linguistics, psychology, and neurophysiology. Of these fields, information science has taken as its concentration the study of "processes [that] include the origination, dissemination, collection, organization, storage, retrieval, interpretation, and *use* [italics added] of information." (Taylor, 1966) Although no consensus exists on the scope of information science (Pao, 1989), few would disagree with the characterization of one major focus as devoted to the study of human information seeking in relation to an information storage and retrieval system.

Research in the information retrieval tradition has concentrated on direct interaction with information retrieval and storage systems, including interactions with humans in those systems. Studies in this area have investigated the representation of a problem for presentation to an information system (see, for example, Oddy, 1977; Taylor, 1968; Ofori-Dwumfuo, 1982)); a user's information seeking and gathering activities (see, for example, Dervin, 1983; Kuhlthau, 1983); and the use of an information system to assist in locating information sources (see, for example, Tenopir, 1988; Fidel, 1991; Borgman, 1986; and Saracevic and Kantor, 1988). These foci are concentrated on those parts of information problem solving which are most directly involved with direct information system interaction. For most information professionals, helping the user find information sources which are relevant (it is hoped) to the user's solution of the information problem is the primary professional contribution to assisting the problem holder in solving an information problem. The provision of the citations to information or of the information itself in the form of documents marks the usual, accepted conclusion of the professionals' participation in a specific information problem solving situation.

A fundamental observation about information gathering and seeking is that it is preferred that they be convenient to accomplish and that perceptions of situational factors are frequently influential in when and how the gathering or seeking is done. Brittain (1982), in summarizing what he terms "hundreds of such studies [of the specific information and document requirements of a handful of scientists in a particular institution] in nearly all fields of science, applied science, social science, administration, and the humanities" says

> Undoubtedly we have a better picture of the average user of libraries and information services than we did twenty-five years ago. An important general finding is that users are not systematic and rational in their seeking after information and knowledge. Indeed, one finding that is common to nearly all the studies is that users do not like bibliographical tools for information and document

> retrieval, do not use them rationally and systematically, and much prefer (often by a factor of 10:1) informal to formal channels of information. (p. 142)

Krikelas (1983) pointed out that the satisfaction of needs may be deferred indefinitely or pursued immediately. Information seeking behaviors are those activities which try to fulfill immediate needs; information gathering behaviors are those which are associated with satisfying a deferred need. Krikelas notes that

> Naturally, for many issues much of the information required would already exist in the individual's memory; only a small part of a person's ongoing needs would produce an outward behavior that we might identify as information seeking (1983, p. 14).

For an internally generated need, one's experience is assumed to be sampled as part of the development of the visceral need. If one's memory holds knowledge, one wouldn't perceive a gap, barring memory retrieval difficulties. For an externally imposed task, a conscious reflection on the task would presumably retrieve pertinent knowledge, thus obviating the creation of an information need.

Information gathering and seeking activities become possible when inquirers formulate some statement of the need. This statement is couched as clearly as it can be considering the lack of knowledge that exists at the time. It represents that part of the need that an individual is able to articulate. It is conceivable that the conscious need could be achieved by self rumination alone. One must be able to conceptualize the need in some form in order to pursue it oneself or to verbalize it in some fashion in interaction with another person. At the same time, it is at this point in Taylor's scenario of question formulation that people begin to interact with others about their need, both for refinement of the need and its ambiguities and for information seeking or gathering.

Krikelas (1983) defined information seeking behavior "as any activity of an individual that is undertaken to identify a message that satisfies a perceived need" (p. 6). A number of behaviors are used for collecting information sources.

The study by Chen and Hernon is particularly enlightening about the sources consulted and their perceived helpfulness by information gatherers and seekers. Chen and Hernon (1981) found that 74% of their respondents turned most frequently to their own experience which was also identified by one quarter of them as the most helpful source (but the least helpful by 16%!). If they fail to resolve an information need by examining their personal memories, individuals begin to search outside resources, most frequently other people, either directly as friends, co-workers or professionals or indirectly through institutions such as stores or government agencies. The second most prevalent source found by Chen and Hernon was consulting friends, neighbors or relatives (57% of respondents). This source was identified as the most helpful source by 15% of those interviewed. Among the twelve non-miscellaneous sources in the study, which accounted for all but 86 situations, only three non-human sources were identified as being consulted. The first was newspapers, magazines or books; the second, TV or radio; and, the third, the telephone book. (p. 138) Libraries were identified as consulted sources, but it is difficult to classify them as human or non-human since it is reasonable to expect that the respondent went to the library for a document or other media (non-human), but he or she may also have had the intention to consult a librarian (human).

Taylor (1968) also indicates in his chart of prenegotiation decisions made by the inquirer that the task of information collection can be analyzed in terms of sources to be consulted. (p. 181) He depicts a series of choices that lead to the stage of interacting with a librarian in order to access and collect relevant information sources. Taylor draws on a 1966 study by Rosenberg to say, "Studies of information-seeking behavior indicate, for example, that 'ease of access' to an information system is more significant than 'amount or quality of information' retrievable" (p. 181-182). This bolsters the observation that information gathering and seeking is driven by convenience among other things. Further, Taylor points out that when the individual is deciding whether to consult an information professional, an important factor is "the inquirer's image of the personnel, their effectiveness, and his previous experience with this or any other library and librarian" (p. 182). The bottom line is that to gather or seek information is a largely underdetermined decision, depending heavily on the perception of ease and value to be achieved by consulting a particular source. Still it is inevitable that, if the knowledge gap is to be bridged, one must acquire the wherewithal (in this case information from someone or someplace) to construct the bridge.

Gathering and seeking, by oneself or in conjunction with someone else, leads to the construction step. What problem holders do with the information sources that have been identified or retrieved for them is, simply, up to them. The problem holders' uses of the retrieved information resources have received less research attention than the areas with direct information professional interaction. Unfortunately, to the person in the throes of an information problem, receiving citations or even a set of documents does not constitute a solution. Rather than a conclusion, it is more properly seen as a beginning. A very important activity--constructing personal knowledge that moves one toward the solution to the information problem--remains to be accomplished. The conclusion for the information problem solver occurs when the information in the sources has been transformed into knowledge in the head and applied to the information problem, yielding a solution.

Recently, several reviewers have recommended that more attention be paid to the information behavior of the human in an information system (Dervin & Nilan, 1986; Hewins, 1990; Kuhlthau, 1991). Users considers themselves still deeply involved in an information system even after they have completed their interaction with the information professional--they still have piles of information sources with which to deal. Recognizing the information need, concretizing it sufficiently to pose it to an information storage and retrieval system, seeking and gathering information, and using the information system to retrieve either leads to or the documents themselves have been preludes to the activity of prime interest--creating the answer to the problem. The use of retrieved and available information resources to answer the information problem is the terminating goal of a search for information. It is during use of the information that the information problem is solved. This may entail related realizations: the information need becomes more fully appreciated; pertinence of information to information problem is developed; information is converted to personal knowledge; and the influence of situational factors is accommodated. Understanding user processes' and their interaction with sources that result from the search stage may enhance understanding of information problem solving, as well as its progenitors, information needs.

Knowledge Use

Knowledge use speaks to one's aspiration for solving an information problem. Specifically, in this study, the phrase indicates the use of the knowledge that is generated in contrast to its more common usage in information science to refer to the use of sources of information, such as documents. The use of documents by information seekers is more properly covered in the knowledge construction component.

Possession of knowledge is not the goal of information problem solving but rather is an intermediate achievement, which enables solvers to continue toward their final goal. Information need and knowledge use are interwoven. Both need and use contribute to the purposive context in which the activity of constructing applicable knowledge is accomplished. Both guide the directing of attention and the creating of inferences, and both contribute to establishing the criteria for the acceptance of a solution.

This concern was also evident in the discussion on situation that appears above. What is the psychological state to begin with, and what are the contextual effects that develop while solving an information problem?

Constructing Knowledge -- The Crux of Information Problem Solving

To this point, the chapter has shown the reader a picture of information problems and most of the interacting components in the problem solving process. With this background, focus now shifts to the one remaining component, the crux of the problem solving process.

A meaningful intellectual effort is needed to understand the information received in response to information collection. After all, the purpose of collecting information is to acquire material which one hopes would aid in easing the knowledge need. The intellectual effort of constructing an understanding from the contents of the literature sources is the key to solving the problem. Regardless of how much information is available, the knowledge gap remains until the construction effort is made.

Information use by the individual (in the sense of using materials to fill the knowledge gap) is not well studied. Fine, in 1984, summarized a review of behavioral research of librarianship with this remark: "Studies of uses and users, as they are conducted today and in the past, give us virtually no understanding of how people interact with information and with libraries" (p. 443). In her discussion of research on information use from the viewpoint of a theory of user behavior, Fine (1984) identifies three concerns, the second of which is ". . . the way in which people interact with information, and under what environmental and psychological circumstances" (p. 447). She goes on to delineate a number of specific questions, including this particular concern: "How does the client's psychological state open up or inhibit the way information is received and processed?" (p.447)

Brittain (1982) highlights use made of information or documents as one of the neglected aspects of user research:

> Very few have paid attention to what happens to documents once they reach users. . . . Use made of documents is related to the virtually untouched area (at least for the information and library profession) of the cognitive processes involved in reading, problem solving, and making use of data and information in the solution of problems and in the creation of new knowledge. Surely it is the intellectual activities--the problems that are solved and the knowledge that is created--that are the raison d'être of library and information services? (p. 145)

Having discovered external sources for filling a need is only the beginning. Comprehending, understanding or making sense of the information in those sources is the crucial operational step in solving an information problem. Knowledge constructing is comprehending or making sense of the world's public information. Constructing knowledge encompasses those activities that individuals perform to transform public or external facts or information into personally held and pertinent knowledge. It is interacting with information that is the crux of the information problem solving process. Interacting with information is the mechanism which converts information into personal knowledge.

It is the specific objective of this study to explore this interaction. The aim is to describe constituent structures and processes. Chapter Two contains an overview of what is known about knowledge construction from related fields of work.

TERMS

A number of terms have been introduced and used with specific senses in this chapter. A selected few are listed below with brief definitions for the reader's convenience.

Information: Data organized by someone else.

Information need: A lack of personal knowledge and the gulf it represents between current position and desired position.

Information problem: The information need and the surrounding personal situation and environment in which the need exists.

Information problem solving: The process of pursuing a solution to an information problem.

Knowledge: Personally organized and held data or information.

Operator: Change agents that transform one state into another.

Problem: Not having something in a current state that is wanted or needed to create a desired state.

State: The problem solver's representation of the features of a problem at a specific time.

CONCLUSION

A study of information problem solving could choose to emphasize any of the problem solving components. This study has chosen to examine the knowledge construction component. Because information problems involve the surrounding circumstances of the problem solver, the study provides an environment by using a version of the Sammy Student scenario as its task setting.

The primary intent of the study is to describe the phenomenon of constructing personal knowledge. Its focus is upon the use of public sources of information by a problem solver to create his or her own knowledge, which bridges the knowledge gap that underlies the information problem and leads to the problem solving activity. Specific objectives are two: (1) to capture the components of situation and environment that are present in information problem solving behavior, and (2) to outline a framework of the structure and processes of personal knowledge construction.

CHAPTER 2. RELATED WORK

Focus

If one were to enter the phrase 'constructing personal knowledge' into a computerized information retrieval system, the chances are one would not retrieve much, if any, desired information on the topic. This phrase is only one way to express the topic of personal mental activity for creating new, private knowledge. In spite of this dearth of responses, the topic it represents has been explored in the guise of a number of closely related phenomena and studied in a number of disciplines that concern the mind, text and reading.

It is the purpose of this chapter to present information from these related disciplines, concentrating on their contributions concerning the research objective and its implementing task. The objective is to move toward an understanding of constructing personal knowledge based on information acquired from written text. The intent is to present relevant knowledge for the task in the study for each of the disciplines. Information from these disciplines necessarily must be selected and focused, since each is a large literature with many ramifications and branches of interest. Focusing tightly on the specific objective and task of this study may omit some information but will at the same time highlight information that is precisely applicable.

Task Components

It should be noted that some researchers consider the entire reading process as

> . . . beginning with the focusing of the eye on the printed page and ending with the encoding of information into long-term semantic memory or its subsequent retrieval for purposes of demonstrating comprehension to someone in the outer world. (Anderson and Pearson, 1984, p. 255)

The disciplines related to the research question of constructing personal knowledge using written text are reading, text comprehension, and attention and memory. To best meet the needs of this chapter, the reading process as described above will be separated into two parts. Writing, more specifically, reading to write, is included because it captures information about the implementing task.

Figure 2.1 shows these as components of the process in the study's situation. The order of processes in the figure is one defined by a rough task analysis; processing by problem solvers is most likely to show iteration and non-linear movements rather than to follow in the strict order depicted in the figure. The problem solver uses the processes as needed.

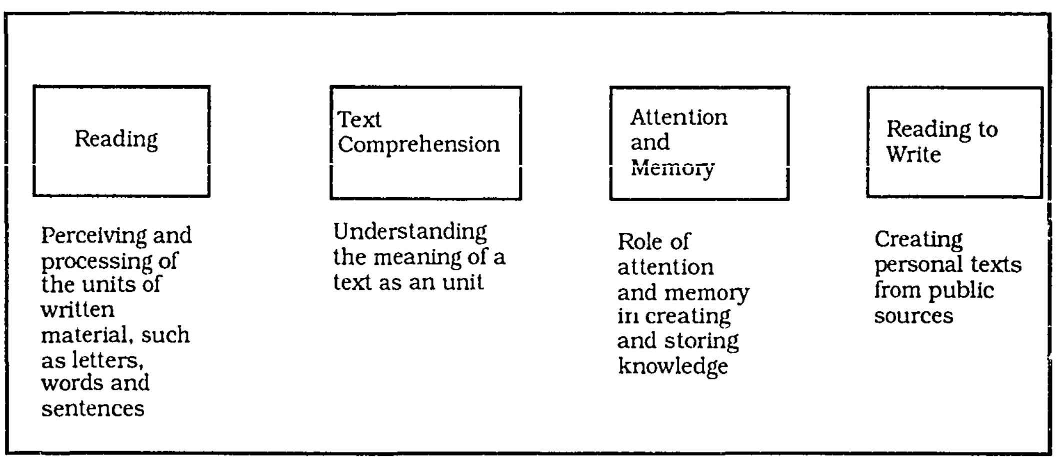

Figure 2.1. Processes that contribute to constructing personal knowledge in the study task

Each of the processes is present during an individual's use of information sources for a task such as the one in this study. Each contributes to the current understanding of the process of reading material that one wishes to understand and use to solve an information problem. None by itself tells the entire story. Constructing personal knowledge requires skills and knowledge from all of them.

READING

Reading is the foundation upon which the other disciplines build and operate. The study of reading concerns the perception and processing of basic textual items such as letters, words, and sentences. Emphasis will be on processing rather than products. In addition, although many reading researchers consider text comprehension as part of reading, reading as discussed here includes only the perception and processing through the written unit of the sentence.

Visual Perception

Although there are other methods that may be used for acquiring information, i. e., using one's tactile sense with a Braille text, for most readers, perceiving printed material is the beginning of information acquisition. The first item of business then is to describe this prerequisite skill of visual perception. (The characterization of the eye and visual perception that follows is based on Downing and Leong's (1982) chapter entitled Seeing and Reading.)

Seeing is accomplished by two specialized organs -- the eyes-- which are parts of the brain that extend beyond the skull. The job of an eye is to refract light waves, converting the electromagnetic energy to nerve impulses. Seeing is an active behavior, with the eyes exhibiting continuous searching and seeking for visual stimuli.

The pupil is the aperture of the eye, passing light through to the lens. Light rays from the environment are focused on the retina, which contains the fovea, an area which is the center of highest visual acuity. The foveal area encompasses approximately two degrees of the total visual field, out of a total range of 180° horizontally and 60° vertically. The parafoveal region extends about 10° around the foveal area and, with much less acuity, serves rather as an alerting zone for movements out of focus. To be seen clearly, an object must be centered on the fovea. It is the task of the eye to transform light into nerve impulses and to feed them to the optic nerve.

It is the task of the optic nerve to transmit the nerve information to the visual processing portions of the brain. It is within the primary visual cortex that the information from the two halves of the visual fields converge. In spite of the tendency to think that the cortex produces a "picture," it is more accurate to say that a neural code has been developed which represents the object in the environment.

This description of the eye and its perceptual processes is brief but sufficient for the purpose of this chapter. The next section discusses the eyes' actions when reading.

Eye Movements and Fixations

Much of reading research on normal silent reading, which is estimated to be about 90 percent of an adult's reading, is done using eye movement and fixation recordings. (Rayner and Pollatsek, 1989, p. 115) This technique is an excellent tool for capturing the real time processes which extract information from text.

The eyes serve as the primary intake sensor for visual reading. The capabilities of the eye for movement rely upon a set of muscles which allow the eyeball to be moved side-to-side, up-and-down, and to be rotated in such a way as to keep the visual fields upright when the head is tilted to one side. These muscles work together for each eye and also in coordination with the muscles from the other eye to produce conjugate movement of the eyes, where both eyes move in the same direction.

Eye movements comprise a part of an individual's active seeing process, enabling one to search for more information rather than to remain a passive receptor. Downing and Leong describe active seeing:

> For example, an object is registered on the periphery of the field of vision; this information is received in the cortex, and the appropriate nuclei in the brain stem receive impulses that produce eye movements and seeing. (p. 142)

Eye movements serve the objective of perceiving and seeing. The technical term for an eye movement which is done voluntarily by an individual to maintain an object within the foveal area of acuity is a saccade, a ballistic move from one location to another. Saccades may be either forward or backward with regard to the text. According to Rayner and Pollatsek (1989), extraction of information is repressed during the average 20 to 35 milliseconds that a saccade takes. (p. 113) During reading, saccades are estimated to use about 10 percent of the total time.

The counterpart of movement is fixation. It is not the case that an eye moves smoothly and continuously across a line of type. Following each saccade is a fixation, a period during which the eye is essentially stationary. Fixations average 250 milliseconds, but have a range from 150 to 500 msecs. (Rayner and Pollatsek, 1989, p. 113) Thus, reading is a well-oiled move and fixate sequence. Rayner and Pollatsek provide a synopsis of the process:

> The eye moves about four or five times per second and jumps an average of about 7 to 9 characters each time it moves. However, it moves back about 10 or 15 percent of the time and there is large variability in both the extent of the forward motion and the amount of time it stays in a fixation. (p. 123)

Of particular importance is the question of what happens during a fixation, since it is during a fixation that information is extracted. Research on activity during a fixation has concentrated on a few issues. One is the amount of information that is available and processed in the parafoveal region. Just and Carpenter (1987) indicate that information in the parafoveal region is ". . . often insufficiently detailed to allow recognition of unpredictable words" (p. 30); Rayner and Pollatsek (1989) indicate that ". . . it is letter information that is obtained beyond the region in parafoveal vision where words can be identified" (p. 137). Thus there is some consensus that some information is processed, but that most usually a reader does not fully identify words beyond the one fixated. (Rayner and Pollatsek, 1989, p. 130)

A related issue is perceptual span, or the amount of a text that is within the effective visual field. Findings show that the span is limited asymmetrically, with the area of greatest information extraction being on the side of the fixated word that is in a forward reading position for the language of the text. (Rayner and Pollatsek, 1989, p. 132) In English, a left to right reading language, the field from which information is extracted is smaller to the left of the fixated word than the field to the right. In Hebrew, a language read from right to left, the area of greatest span is to the left, the direction of normal reading. (Rayner and Pollatsek, 1989. p. 134)

In English, the left field provides little information and becomes irrelevant since it is not attended to by the reader. The size of the right span in English is approximately 15 characters extending from the beginning of the fixated word; characters beyond this are used very infrequently in normal reading. (Rayner and Pollatsek, 1989, p. 132)

This brief review of perception and the process of seeing serves to support the discussion to follow about deciphering letters and forming words.

Word Recognition

Word identification has enjoyed extensive study within cognitive psychology. As a basic unit of reading, it is not surprising, then, to find that common to most theories of reading is the underlying realization that before syntactic or semantic processing may be done, the words that comprise the sentence must be recognized. As Gough (1984) describes the process,

> It begins with a pattern of light and dark cast onto the retina by reflection from the printed page; for the skilled reader, it ends less than a quarter of a second later and almost always with the correct word. In this time, the reader must find the word's meaning in memory, for only there is word form associated with meaning; he must locate a single item in a

> mental lexicon containing tens of thousands of entries (cf. Gough, 1975). (p. 225)

Letter versus Word as the Recognition Unit

How this is accomplished is the subject of study and a matter for disagreement. Part of the dissension arises in choosing a unit of text to study. Bradshaw has called this difficulty the "search for the elusive entity" (1975; cf. Downing and Leong, 1982, p. 197) . The choices are shown below in the hierarchy of parts that obtains for a word:

Features -----> Letters -----> Words

Each of these units has been the center of concentrated study. Beginning with features, there is compelling physiological evidence that feature detection exists in the visual organ. (Hubel and Wiesel, 1962,1963, 1965; cf. Downing and Leong, 1982, p. 197) E. Gibson developed a theory of distinctive features, which considers that the visual features of letters are composed of straight lines and curves ones, forming a characteristic set for each letter. (1969; cf. Downing and Leong, 1982, p. 198) Thus, to perceive a letter, one must differentiate, categorize, and interpret the input signal of lines and curves to determine which set is being viewed. Gibson maintains that perception is an abstraction process of discovery.

Other researchers concentrate on letter clusters, suggesting that it is a letter or a cluster of letters that serve as the perceptual unit of word recognition. The basis for a grouping may be either phonologic or orthographic information. There is some evidence that both positioning of letters around a vocalic center (the sonorous or resonating part of a syllable) and the syllable help in the identification of individual letters. (cf. Downing and Leong, 1982, p. 199-200)

Forster (1990) presents a synthesis of lexical processing that recognizes two lines of argument concerning how a word is recognized: (1) the process is dictionary-like, involving a look up of the meaning of the item in a list; and (2) the process is pattern driven, involving the detection of letters with the subsequent elicitation of the word and its meaning. In Forster's view, both represent an associative process, one in which an item as stimulus is associated with an idea as responding elicitation.

In general, approaches to the word recognition problem may be classified as letter detection, word detection or a combination. Pollatsek and Rayner's (1989) position is an example of a classification of word recognition models: direct word-recognition models in which letter recognition is irrelevant to word recognition; serial letter models, in which serially processed letters are recognized before words; and parallel letter models, in which letter information is fed in parallel into word detectors.

Rayner and Pollatsek (1989, pp. 75-83) elect an intermediate position. They support the position that letters are processed in parallel and result in the identification of the word. They rule out serial letter-by-letter processing based on the finding that words (letters in related groupings) are reported more accurately than letters in isolation, an effect that is known as the word superiority effect. This would not be expected if letters are processed serially-- a single letter should be processed more quickly than a word. In addition, they state that words are not visual templates, to be matched in a template system of identification. There is evidence from the ease of recognition of novel forms of the lexical item that work against the idea of template matching.

Just and Carpenter (1987, p. 43) distinguish between word encoding and lexical access. It is the translation of the printed symbols into a visual form and the access to this form in the lexicon that combine to identify a word for a reader. Distinction between these processes is supported by the existence of situations in which only one of the two processes occurs. One process is shown by the tip-of-the-tongue state in which a person accesses the meaning of a word but is unable to give the word itself. This state is familiar to crossword puzzle workers. The other process shows that a word that is totally unfamiliar (such as *shagreen*) may be encoded, but no meaning is accessible for it. (Shagreen is an untanned leather covered with small round granulations and usually dyed green (Webster's Ninth New Collegiate Dictionary, 1984, p. 1080).)

Visual Words and Sounds

A related issue to letter versus word as unit of recognition is that of the role of sound coding in the process. Sound for a word, i.e., how to say the word, is available within a half second in most cases. This raises the question of whether sound supports access to lexical meaning or whether the access from visual percepts makes the sound code available. The role of internal sound representations is still one of controversy among reading researchers, according to Pollatsek and Rayner (1989). They discuss evidence for the issue of sound coding and word identification and sum up the findings:

> It appears that sound codes are involved in some way in the identification of visual words. The fact that irregular words are correctly identified indicates that irregular words such as ONE cannot be identified *only* by going through rules or analogies to access sound and then the sound to access meaning. On the other hand sound codes do appear to be involved in the access of meaning of a word because the regularity of the spelling of a word affects lexical decision time, and homophones are confused in a categorization task. (p. 416, emphasis in original)

This seems to leave the question somewhat open. Since verbalization is involved in this study, it is enough to know that there does not seem to be interference between the sound and its meaning for a word. This relieves a concern for task interference when one is saying aloud what is in one's mind.

Immediacy and Eye-Mind Assumptions

One other concern must be addressed before moving on to the processing of larger units of expression. When is processing done? That is, does a reader process each unit (whatever that is) as it is found or are there natural occurring boundaries in the presented text that signal the point of processing?

Just and Carpenter are the proponents of a theory of reading that addresses this timing issue. It is their contention that readers deal with each word as they encounter it (the immediacy assumption) and that the processing is done while the word is at the center of attention, i.e., fixated (the eye-mind hypothesis). This is a claim of tight coupling of each and every eye fixation to a reader's concurrent cognitive processing. Just and Carpenter's evidence for these assumptions was collected during experiments using gaze duration as the measured variable. A gaze is a combination of successive fixations on the same word, and its duration is the compilation of total time spent during those fixations.

In essence, gaze duration evidence shows that gaze duration is affected by the word's length in number of letters, which affects the encoding of the word; by the word's normative frequency in the language, affecting its time to access in the mental lexicon; and by the syntactic and semantic difficulty of the word, affecting its resolution within a larger unit. An increase in processing load is matched by an increase in processing time as indexed by the gaze duration. (Just and Carpenter, 1987, p. 41) Just and Carpenter posit that "the evidence shows immediacy at several levels of interpretation" (p. 41), including the lexical, syntactic, and textual, and thus supports both the immediacy assumption and the eye-mind hypothesis.

In this view, little spill-over of processing occurs between fixations. This is supported by gaze duration data which show no extra processing time for the word following a difficult word but which show lengthened processing during fixation of the difficult word itself. (Thibedeau, Just and Carpenter, 1982; cf. Just and Carpenter, 1987, p. 41)

The immediacy assumption is not unchallenged. In particular, Rayner et al (1980) discuss the integration of information across fixations, presenting evidence that there is some facilitation of processing of the next word under certain conditions. The position is that words are processed on more than one fixation. The question that is asked is what information from the word adjacent to the fixated word in the direction of reading is extracted and then integrated when the word is fixated itself? This issue is studied by changing the letters of the word during a saccade, so that sometimes letters of the word as processed in the parafovea and of the word in the fovea during fixation are the same, and sometimes not. The major finding in this area is that if the first two or three letters of the adjacent word are the same as the letters in the word that is eventually fixated, then extraction of information is facilitated. (Rayner et al., 1980) This facilitating effect of the first three letters in the parafovea is explained by Rayner and Pollatsek as being the result of the excitation of a neighborhood of related lexical items, including the correct one, all sharing the same beginning letters, to some level of activation below the threshold of identification. The subsequent fixation allows the faster identification of the word because of this partial excitation. (Pollatsek and Rayner, 1989)

Kolers also questions whether subjects are attending if they are looking. The suggestion is that there may be "cognitive lag' in processing, where the mind lags the eye, or a "cognitive overlap" where the mind is ahead of the eyes' position. (Kolers, 1976; cf. Kennedy, 1987, p. 171)

Kennedy raises another concern with the immediacy assumption based on experimental results of Fisher and Shebilske. If non-fixated means not processed, which is a reasonable implication of a position that claims processing for fixated words, then recall of skipped words should be the same for subjects for whom words were present but not fixated as for those for whom the words were absent. But this is not the case. The group for whom skipped words were present but not fixated recalled significantly more of these words than a group for whom words were not present. (Fisher and Shebilske, 1985; cf. Kennedy, 1987, p. 171-172) This indicates that non-fixated words do receive some processing.

Kennedy concludes ". . .consequently the 'immediacy hypothesis' must be challenged" (Kennedy, 1987, p. 172).

It is somewhat problematical to compare these positions since they consider different levels of attention, the single fixation versus a gaze. In spite of these differences, the preponderance of evidence seems to warrant the inference that the majority of processing occurs during the time spent fixating, or more properly, gazing at the word in question.

Sentence Processing

The next level of processing concerns the sentence. It is at this level of language units that one begins more clearly to see the process of integration, which is so necessary to comprehension. Emphasis in this discussion will be on the performance of humans in comprehending, which is the extraction and storage of meaning from utterances of another; discussion of formal grammars, linguistic theories of language and of language production are of less concern for this study and will be included only as needed to support the discussion of comprehension performance.

It is appropriate to begin with a look at influences that permeate the comprehension process and that produce a compromise among contending tendencies. According to Carroll, comprehension is influenced by structural, functional and processing factors. (1986, pp. 176-182) Structural considerations recognize that we in some way recover an underlying representation of a sentence from characteristics present in its surface representation and that this surface structure mediates the ease with which this recovery is made. Structural ambiguity calls upon the comprehender's knowledge of context, syntax and semantics for resolution.

Functional influences are directly related to interpersonal communication. Participants recognize not only direct but also indirect speech acts, as well as working within a framework of conventional conversational procedures. Consideration of direct speech acts, those directly related to the content of the utterance, is concerned with the intentions of a speaker and interpretations of those intentions by listeners, coupled with both communicators' knowledge of prevalent social parameters for communicating. Indirect speech acts tackle the circumstance of a speech act whose intent is not conveyed in the words used, but resides in the conventions or context of the utterance. For example, "Can you pass the salt?" is produced by the convention of politeness, which prevails upon the speaker to produce a request in the form of a question, rather than in the form of an imperative, such as "Pass the salt." The conventions of concern extend beyond those of social behavior to expectations of proper and accepted procedures for communicating.

Carroll's (1986) processing consideration of interest is the mismatch of required and available capacity for the task of extracting meaning from a sentence. Limited working memory calls for techniques of timely and selective processing that provide a trade off of time, strategies and capacity.

Carroll (1986) also describes sentence comprehension as a multistage process: (1) extraction, recovering of the underlying structure of the sentence; (2) interpretation, deriving the meaning intended by the speaker or writer; and (3) retention, storing some or all of the meaning permanently. (p. 176) Discussion of retention will be reserved for a later section. This section continues with brief treatments of the first two, commonly known as syntactic analysis and semantics.

Syntactic Analysis

Recovery of the syntactic structure of a sentence is called parsing. Mitchell (1987) refers to two kinds of structural decisions that must be made by a reader: one concerning syntactic labels for strings of words and the other specifying the relationship between the different linguistic objects. (p. 87) Parsing uses parts of speech (nouns, pronouns, verbs) in conjunction with a grammar to determine a functional category (subject, predicate, object) for the components of a sentence and to develop a representation of the relationship of these categories. Parsing, by taking a sequence of words, organizing them into higher level units, and associating these units using grammatical relationships, produces the underlying constellation of concepts from the sentence.

Just and Carpenter (1987) identify a number of textual cues that aid the comprehender in constructing a syntactic structure for a sentence: word order, word class, function words, affixes, word meanings and punctuation. Briefly, word order refers to the serial position of a word in a sequence of words as a device relied upon by a language to indicate the syntactic role of a word. In English, subjects generally appear before verbs. Word class consists of the part of speech categories mentioned above, which are implicitly relied upon by a comprehender for associating a word with a role. Function words comprise a specialized word class that is of particular use in syntactic analysis as a signal of the beginning and even the type of a new syntactic constituent. Affixes also cue a word's syntactic role. For example, in the sentence "The old train the young," adding the affix -ed to the end of train eliminates the pending ambiguity of train as a noun or verb. Word meaning also acts as a cue to the role of a word, since many words make sense in only some positions and roles. An example is the word mustard, which one would not expect to find as the subject of a verb requiring an animate object, such as in "The mustard thought that. . . ." The final cue is that of punctuation, which signals boundaries of sentences and clauses, serves to segment the word stream for a reader, and may cue syntactic and semantic roles by use of specialized symbols such as quotation marks and exclamation points. (pp. 136-143) Chafe suggests that punctuation also serves to ". . . tell us something about a writer's intentions with regard to the prosody of that inner voice" (Chafe, 1988, p. 397). "That inner voice" refers to his observation that ". . . writers when they write, and readers when they read, experience auditory imagery of specific intonations, accents, pauses, rhythms, and voice qualities, . . ." (Chafe, 1988, p. 397).

These cues converge, with each type of cue constraining the range of possible syntactic interpretations. Just and Carpenter warn about reliance upon a single cue: "However, a single cue can sometimes be weak or even misleading, so it is the conjoint constraint imposed by all the available cues that leads to the correct interpretation" (p. 137).

There is ongoing exploration into the timing and flow of processes that use these cues to produce syntactic structures. Most researchers agree that construction of the syntactic structure is begun or continued as each word is encountered in the sentence, but they do not agree upon the seriality of processing. Just and Carpenter's position of immediate and full processing of the encountered word, explained previously, also obtains for their position on syntactic processing; interpretation proceeds immediately and encountered problems are handled by backtracking. Other researchers think that the human parser is deterministic, making use of a lookahead facility for disambiguation of structural anomalies (Marcus, 1980). Yet others ascribe syntactic processing to procedures other than the construction of phrase structures, such as, for example, to the determination of lexical properties of verbs and other words which require certain attributes in order to function properly. (Ford, Bresnan, and Kaplan, 1983; cf. Rayner and Pollatsek, 1989, p. 246)

Two parsing strategies that humans appear to use have been discussed by Carroll (1986). The first is the use of a function word to set up a new constituent, mentioned above by Just and Carpenter as a textual cue. The second is the use of minimal attachment, by which a parser takes the first available rightmost structural option and changes it only when required to by subsequent input. For example, in the sentence "The old train the young" shown above, the first option is to consider "train" as part of a noun phrase; occurrence of "the young" signals a mistaken judgment and calls for correction of the structure being built. The minimal attachment strategy reduces the processing load, a prime concern when dealing with a limited capacity such as that exhibited by human working memory.

Semantics

Although the exact flow of processing of syntax is not agreed upon, it is an agreed tenet of sentence comprehension that capturing structure is not sufficient by itself to do the job. It is also necessary to unravel and resolve the concepts that are present. The contributions of semantic features and roles of words fit together to move the comprehender toward overall sentence meaning.

Rayner and Pollatsek (1989) refer to the semantic features of word meanings. That is, a word meaning is presumably represented by a set of features such as "spherical," and "three dimensional," for features of a ball. These features act as input to the process of resolving semantic ambiguity. It is this bundle of word features interacting with each other that disambiguates a possible semantic anomaly. (p. 253-254) For example, in a sentence like "The pitcher stood on the mound," it is the combination of features of the words "pitcher" and "mound" that determines the most likely interpretation of pitcher as a person. In contrast, the combination of "pitcher" and "sideboard" favors the interpretation of pitcher as an object in the sentence "The pitcher stood on the sideboard."

For Just and Carpenter (1987), semantic analysis refers to ". . . the process of recognizing the roles of people and objects that are part of the action or state described by a clause" (p. 167). This draws attention to three kinds of information, which depends upon the roles required by a particular verb: roles played by participants' in a state or action; the state or action; and the surrounding circumstances. (p. 169) Using the verb "give" as an example, participants roles would include giver, recipient and object given; state or action would be the giving; and the circumstances would be where and when the giving occurred. These types of information lead to an understanding of the concepts embodied in clauses of sentences and aid in the construction of a mental representation of the relationships expressed by that sentence.

Autonomy of Syntactic and Semantic Modules

Most students of sentence processing admit that ultimately comprehenders use all the knowledge at their disposal to understand a sentence. (Clifton, 1991, p. 96) A remaining active research question is the separability and interaction of the modules that apply syntactic and semantic processing to the words of a sentence, particularly the modularity and autonomy of the processes.

Fodor (1983) has provided a useful analysis of modularity in cognition. A module is commonly considered to be an independently acting process which is adapted to perform a particular, relatively simple computation in an efficient way. Among the properties of a module is that of information encapsulation, meaning that the module is sensitive to a limited range of stimuli and operates without regard to the current value of other kinds of information. Communication between modules is through a narrow band that passes only those types of information that have been determined by some principle of the theory to be common and needed between modules.

Clifton (1991) points out that "We have to look at the moment-to-moment or "on-line" processing of a sentence if we are to learn anything specific about the function of any linguistically specialized system" (p. 98). To this end, a number of researchers have attempted to use on-line procedures such as eye movements and self-paced reading to determine the modularity and autonomy of syntactic processing.

The occurrence of a temporary ambiguity in a sentence allows that ambiguity to be used as the object of investigation. A temporary ambiguity occurs when a sentence fragment may be followed by more than one concluding structure. For example, "The man left . . . ." is ambiguous in that it may completed in a number of different ways, i.e., The man left *after dinner*; the man left *his briefcase*; the man left *home*; the man left *at home felt sad*. Since people deal with these ambiguities in processing sentences, the occurrence of the ambiguity presents a natural artifact and opportunity for determining the existence of distinct modules in language processing. (Clifton, 1991, p. 98-99)

Answers to the question of modular autonomy lie along a continuum from none to complete autonomy for a module. As one might expect, there are researchers who advocate each position.

Conveniently, several researchers who prefer something other than total interaction refer to the same reported experimental findings. The findings of interest arise from two sets of experiments: one by Rayner et al. in 1983 and the other by Ferreira and Clifton in 1986. Rayner et al. relied upon the temporary ambiguity introduced by two types of sentence fragments, differing in their semantic opacity but similar in that both could be interpreted in one of two ways. In the sentence "The florist sent the flowers was very pleased with herself." the string *the florist sent the flowers* may be interpreted either as a simple active sentence or a reduced relative clause (reduced from *who was sent the flowers*). A fragment which was considered less semantically ambiguous, *the performer sent the flowers*, was used as a foil. Through a comparison of the readers' eye movements and the lengths of their pause and how much they slowed their reading paces at the point of disambiguation (*was very*) of these two types of sentences, they concluded that "readers initially pursue just one syntactic analysis of a sentence, but that they arrive at the semantically and pragmatically plausible interpretation of sentence, even when that interpretation is not structurally preferred" (cf. Rayner and Pollatsek, 1989, p. 258-259). This position on modular autonomy maintains that the syntactic parser works independently and that semantic influences occur later in sentence processing. The disambiguating circumstances alert the comprehender to back track and repair the structure that has been developed to date.

Clifton (1991) suggests that the creation of a single structure conforms to a principle that syntactic modules use: that of accepting the first available analysis, referred to as the minimal attachment strategy. If such a strategy operates unaffected by meaning, pragmatic information or contextual plausibility, then the module is operating independently.

Clifton relies upon Ferreira and Clifton (1986) to support the conclusion that the minimal attachment strategy does operate without being affected by meaning or discourse context. In this experimental set, the temporary ambiguity was resolved by the use of prepositional phrases, with a variation in these phrases such that one would presumably prefer a minimal attachment strategy and one would not, for semantic reasons. For example, one sentence might be "The defendant examined by the lawyer turned out to be unreliable," whereas the counter example might be "The evidence examined by the lawyer turned out to be unreliable." Ferreira and Clifton considered the version using evidence to be semantically unambiguous because evidence is not animate and examined requires an animate agent.

Another position, advanced by Tyler and Marslen-Wilson, is discussed by Carroll (1986). This is the view that syntax and semantics interact continuously throughout the comprehension process. (1977; cf. Carroll, 1986, p. 190) If decisions on sentence structure are made immediately rather than waiting until the end of a clause, as Frazier and Rayner supports, then it is likely that this initial assignment used more than syntactic information. (1982; cf. Carroll, 1986, p. 190)

As one would anticipate, Just and Carpenter (1987) also support the full interaction position. They maintain that "semantic and syntactic analyses are applied to each word of text as soon as it is encountered either by a reader . . . or a listener. . . " (p. 189). With such a position, they accept the findings from Rayner et al. with "some reservation, because the manipulation was a relatively weak one" (Just and Carpenter, 1987, p. 191). In their opinion, the weak semantic influence "does not warrant" overruling the strong syntactic evidence. They suggest that the finding would be better supported if based upon a stronger implausible agent, such as "The dog sent the flowers was very pleased."

The bottom line seems to be that there is some evidence, though somewhat weak for some, that the syntactic parser works alone at least some of the time. Garrett (1990) sums up the state of the art in sentence processing with this to say about modular autonomy:

> These questions [concerning the interaction of semantic and pragmatic information with syntactic structure building] are under active investigation, but it is quite clear that some truth attaches to both sides--there are unquestionably some syntactic processes that are indifferent to the presence of

> semantic constraint, and indubitably some processes susceptible of a pristine syntactic description that nonetheless reflect semantic influences. (p. 167)

It is equally clear that no researcher is convinced that a parser does the entire task of comprehension. Somehow, a comprehender melds the strategic and discourse factors with the syntactic constraints to produce real-time solutions.

Rayner and Pollatsek (1989) conclude their discussion of words and sentences "on a note of cautious optimism. While our present knowledge of how sentences are read is meager, the basic outline is in place." They go on to note that "a significant number of interesting psycholinguistic theories" and "a variety of interesting paradigms" are evident in the field and should provide substantial progress in sentence understanding as they are pursued. (p. 263)

Summary

Reading has been considered from perception of a written symbol to the processing of a sentence. There is general consensus on the processing path and that different types of knowledge are essential and are involved in the comprehension of a sentence. Whether accomplished by feature extraction or holistically, word recognition is a vital part of constructing the meaning of a sentence. At the same time, comprehension of a sentence is found to involve more than lexical access, since the way in which the words are put together also is essential to deciphering the meaning of the whole. "John loves Mary" and "Mary loves John," are not the same, syntactically, semantically nor, as a divorce action attests, pragmatically.

Reading is a large component of the task used to explore constructing personal knowledge in this study. It is the most prevalent method for obtaining information in the study and as such requires and deserves to be understood for its contribution to information problem solving. The ability to construct meaning for a sentence is an essential accomplishment in the acquisition of new information.

TEXT COMPREHENSION

Word and sentence processing will achieve a "meaning of the sentence," but in order to achieve a "meaning of the text," it is necessary to integrate sentence meanings. Clancy (1993) reminds us that comprehending is a dynamic process, requiring more than discrimination of building blocks:

> A person interpreting a recipe, diagram, or journal article is conceiving, not merely retrieving and assembling primitive meanings and definitions according to rules of grammer [sic] and discourse structure. . . . Information is created by the observer, not given, because comprehending is conceiving, not retrieving and matching. (pp. 90-91)

This section will consider the next level of word arrangement, the text. Halliday and Hasan's definition is ". . . any passage, spoken or written, of whatever length, that does form a unified whole." (1976, p. 1) Usually, one considers a written text to consist of sentences, separated into groups, and somehow related. Haberlandt and Graesser, differentiating between word-, sentence- and text-level processing, specify that it is at the text level that topics are identified, knowledge activated and sentences integrated. (1985; cf. Colley, 1987, p. 113)

Because types of text may differ in their cognitive structures, the large literature on story and narrative text is used sparingly in this overview, which focuses on expository or descriptive text comprehension. (Brewer, 1980, cf. Colley, 1987, p. 114)

Comprehension is considered a constructive process of understanding text in context. There are two major types of knowledge that are intertwined in the understanding process. One, text-based, concerns what a text, its organization and its presentation, provides to the reader to aid in the understanding of the creator's message. The other, knowledge-based, concerns the background of organized knowledge that is unique to a reader and which is applied interactively during the comprehension process.

Use of Text-Based Factors

There are a number of factors present in the text itself which contribute to a reader's understanding of the text. These factors range from typographical cues to content organizing features to contextual constraints and boundaries.

Visual Cues

An obvious cue to text structure are a number of features of the physical presentation of the text. Typographic cues include such devices as interlinear space variations and different cases, type size and type weights (normal, bold, italicized). The use of textual organizing features such as subheadings or margin notes, or patterning techniques which highlight selected categories of text (summary, headings, main points) by underlining or printing in a different ink color also contribute to visual cueing. (Foster, 1979) Human factors researchers pay attention to factors of text presentation such stroke width, width-to-height ratio of a character, styles of type, size of type, case, interletter spacing, interline spacing, types of sentences, and order of words for purposes of display visibility, legibility and readability. (Sanders and McCormick, 1993, pp. 102-110)

Foster (1979) finds that

> This literature on cuing indicates that although some negative findings have been reported there is considerable evidence that typographical cuing can benefit scores on a post-test, and that the effect has been demonstrated most frequently with immediate post-tests." (p. 191)

(Comprehension is frequently measured by testing a subject after he or she has read a text.)

Cohesion and Coherence

More central than visual cues to developing an understanding of the semantics of the discourse are those features which aid in the reader's construction of a coherent text. A coherent text is one which ". . . must have a consistent theme and the events or arguments which comprise the theme must be organized logically within the text." (Colley, 1987, p. 128)

Coherence depends upon devices of cohesion. Cohesion is defined by Halliday and Hasan as occurring "where the INTERPRETATION of some element in the discourse is dependent on that of another. The one PRESUPPOSES the other, in the sense that it cannot be effectively decoded except by recourse to it." (p. 4, emphasis in original) They identify five types of cohesive ties: reference, substitution, ellipsis, conjunction, and lexical cohesion. (1976, p. 4) Linguistic reference uses those items in a language that allow one to point to something else for their interpretation, instead of being interpreted semantically in their own right. References may be forward or backward to other items in a text. (p. 31) Substitution is the replacement of one item by another and differs from reference by being a relationship between wording rather than meaning. (p. 88) Ellipsis, a different structural mechanism for relating words, is the omission of an item, a substitution by zero. It is "something left unsaid, but understood nevertheless" (p. 142). Conjunction is "a specification of the way in which what is to follow is systematically connected to what has gone before" (p. 227). It indirectly relates meanings, rather than words, which presuppose the presence of other components in the discourse. Lexical cohesion is the effect achieved by the selection of vocabulary. (p. 274) It is an example of the general phenomenon of reiteration, in which one lexical item refers back to another, to which it is related by having a common referent. Examples would be using a repetition of a noun in two clauses or sentences, using a synonym for an item, or using a superordinate term for an item. (p. 278)

Clark and Haviland suggest that a general strategy for presenting successive pieces of information is the given-new strategy. The idea is that text, a sentence in particular, contains two kinds of information, one which refers to previously presented material (the given) and one which contains new material (the new). Each sentence, by containing both kinds, provides a means to establish continuity in succeeding sentences.

(1977; cf. Colley, 1987, p. 129-130) Inferences play a major role in this strategy, since the reader interprets the relationship between the two kinds.

In addition to linguistic cohesion devices identified by Halliday and Hasan and the sentential technique of Clark and Haviland, Colley points out that thematic cohesion is also necessary. Thematic cohesion follows from logical continuity in a passage, deriving from maintaining spatial continuity, continuing with a point of view and other techniques that tie sentences together. (1987, p. 129)

Use of Knowledge-Based Factors

A reader's comprehension of a text is also influenced by his or her personally held world knowledge. Appropriate background knowledge of events, actions, processes and circumstances enables a reader to connect explicit content statements, to resolve ambiguous material, and to establish a contextual base for the unfolding text. Graesser outlined six basic knowledge domains involved in text processing. Of the six types, five are based on world knowledge of one kind or another: linguistic; causal; intentional; spatial; and roles, personalities, and objects. Only one, rhetorical, is based on the form and conventions of the text itself and even it relies upon the reader's prior experience in the world with a type of text for its relevance. (1981; cf. Colley, 1987, p. 113)

The enabling skill which brings world knowledge to bear during comprehension is that of inferencing. It is the ability to fill in the implicit connections between explicit statements that moves a reader from the position of understanding the sentence to understanding the text.

Inferencing

Inferencing is a mainstay of making sense of a text. By inferencing is meant the "reading between the lines" that readers do in order to connect elliptical statements in a text into a coherent memory. (Seifert, 1990)

A useful classification of inferences has been proposed by Swinney and Osterhout (1990). Based on differing values of immediacy, automaticity, and mandatoriness as criteria, two categories of inferences are possible: perceptual and cognitive. Perceptual inferences are drawn as soon as the licensing conditions for that inference are met; they are drawn automatically without recourse to world knowledge or pragmatic influence; and they are drawn in spite of discourse conditions which would predict their inappropriateness.

Cognitive inferences on the other hand are those at the other end of the values for the criteria. They are not automatic but are under the control of the comprehender who may choose to exercise strategies based on world knowledge, statistical bias, or pragmatic knowledge. As a result, cognitive inferences are not immediate in the same sense as perceptual inferences, and neither are they mandated by the circumstances of their occurrence. (p. 19-20)

Swinney and Osterhout suggest that perceptual inferences are limited to those which involve co-reference, particularly explicit and implicit anaphoric elements. Cognitive inferences encompass pragmatic types of inferences such as predictive, causal, metaphorical and schema-based. (p. 20-21) Empirically, they find that timing is the major distinction between the two theoretically distinguished positions, and that a distinction between immediate and later-occurring processing is exhibited in appropriate tasks (for example, pronominal anaphoras for perceptual and metaphoric meanings for cognitive).

Since perceptual inferences are automated, they are performed without conscious attention by the reader and are by definition, unreportable. (Eysenck and Keane, 1990, p. 118) Cognitive inferences, on the other hand, are reportable, and thus become the target of researchers who want to better their understanding of real-time inference construction during comprehension.

An important question is what inferences are in fact made as opposed to those that are in principle possible. Seifert (1990) suggests that in general pragmatic inferences are drawn in response to three factors: utility of an inference to ongoing processing; past utility in the form of default values; and processing context as represented by reader goals. (p. 105)

Among the types of inferences that have received attention from researchers are bridging inferences (Singer et al., 1990; Abbott & Black, 1986); elaborative inferences (Whitney & Williams-Whitney, 1990) and summarizing inferences (Johnston & Afflerbach, 1985). Bridging inferences are those made to establish or maintain coherence; elaborative inferences, those made from a reader's knowledge to fill in gaps or details not mentioned in the text; and summarizing inferences, those made to derive main ideas from explicit statements that warrant identification as points of major importance to the exposition.

An important point is made by van Dijk and Kintsch (1983) in regards to elaborative inferences in particular. Although the emphasis in studying inferencing is on their contribution to the construction of the meaning of a text, inferences may also mislead, thus giving rise to a meaning of text that is distorted in some sense from that intended by its creator. (p. 52) This holds true for any inference; the possibility of misdirection as well as appropriateness is always present. What is meant by "misdirection" is simply a moving away from the intention of the speaker (locutionary act) toward one interpreted by the listener (illocutionary act). Since the primary purpose of expository text is to convey new information about a topic, a mismatch may cause communication to fail. The reader may not create a meaning that conveys the speaker's intended message. That this is not the intention of communication is also remarked upon by van Dijk and Kintsch:

> This communicative assumption may mean, among other things, that the listener does not merely attempt to construct his or her own representation of the story, but matches this interpretation with a representation of the assumptions about what the speaker intended the listener to understand. (p. 7)

Context

One of the more important inputs to inferencing processes is the context or circumstances of the reader's situation.

Context is like an illusion, being able to be either ground or figure. From one viewpoint, it is the milieu in which events and humans co-occur, that is, the ground. From another, it is the boundaries that separate the whole from the particular, that is, the figure. As ground, it is described as encompassing the totality of the surrounding circumstances of the situation; as the figure, it is discussed in terms of constraints that guide and direct by restricting movement or establishing boundaries for actions or mental events.

This illusionary quality makes context difficult to pin down, with almost everything considered context by someone at some time or other. It is, in a sense, the junkyard of psychological studies. If a researcher does not plan to incorporate a circumstance in a study, the circumstance becomes part of the context for the study. Then, the researcher accommodates it by mentioning it briefly and, if possible, deleting it from the experiment's environment.

At the same time that one set of researchers is trying to ignore or at least ameliorate context in its role as ground, another set is attempting to recognize that human behavior is not found in a vacuum and that it is context that provides the definition; that is, they treat context as figure. For this set, humans, situated in specific social and cultural circumstances and enmeshed with particular factors of place, time, space and age, not only are influenced by these very factors but also, in a very real sense, are formed and created by them.

It will be no surprise that text comprehension is concerned with the intricacies of context. Given its reliance upon inferencing, comprehension of text requires a rather extensive interaction with the idea of context as representative of world and situation knowledge. Unfortunately, as Carey and Harste (1987) note ". . . it has been rare to find a research (or theoretical) study that takes the variable [context] into account in any meaningful fashion" (p. 189).

Recognizing that to consider all possible contextual factors involved in a situation would be nearly impossible, Carey and Harste recommend adoption of the notion of register, which, by determining linguistic features typically associated with a configuration of situational features, would establish a circumscribed relationship between situation and text. (p. 193) Carey and Harste build on Spencer and Gregory's limited taxonomy for style. (1964; cf. p. 194) Three components, i.e., field, mode and tenor, are viewed as sufficient to compose ". . . a framework for assessing the various stimuli that the reader selects as important cues from the environment" (p. 194). Field would encompass the content of the message and its semantic intent; mode, the language activity of the event, ranging from specific linguistic properties of the situation to a number of physical characteristics; and tenor, interrelationships among the social roles involved in the communicative event. (p. 194) With this arsenal of mapping features, each unique event could nevertheless be recognized as an instance of a general or typical situation, and thus studied in a generalized fashion.

Text Comprehension Models

The myriad elements that have been discussed in this overview are the stuff of which text comprehension is constructed. A number of hardy and adventurous souls have attempted to combine the individual processes of text comprehension into models of the entire process. They have aimed toward a representation of a person reading.

In creating these models, the modelers have exercised a variety of options along several dimensions. One choice found in all models of interest to this overview was that of building a model at the level of psychological processes rather than at the level of physiological processes. That is, the concern is to model and present a model at the level of program, i.e., software for a computer, rather than at the level of physical implementation, i.e., hardware. This choice opts for a goal of understanding the relationship of observable behaviors to the hypothetical structures and processes of reading comprehension. At the same time, it does not say anything about the implementation of the program on a specific device, such as a human. For most model builders who are trying to present a model of *human* processing, model constraints are imposed that shape the model to known human capacities and limitations. Newell was a particularly strong advocate of this endeavor. (Newell, 1990)

A second dimension available to modelers is the choice between top down and bottom up processing. This choice is usually theory-based. That is, if the modeler theorizes that the processes of interest derive from the data in a building-from-piece-to-piece manner, the model is likely to represent processes as being data-driven. If the modeler expects that knowledge from top level processes influences or even controls constituent, lower level processes, then the model will present an architecture that allows effects from higher level processes to trickle down. And, some modelers allow for both types of influence. Processing based on a combination of data and knowledge is more usual than pure data or pure knowledge processes, particularly for a complex skill such as reading comprehension.

Modelers have chosen a number of different representation methods for comprehension models. Among the preferred methods have been propositions, schemata and mental models. Propositional representation is the coding of text statements into a predicate or propositional logic form. This allows for comparisons and logical deductions between propositions. (van Dijk and Kintsch, 1983) Schemata are frameworks that may store and organize both background and specific instance knowledge about a concept or event. They are preferred by top down processing systems because of their store of knowledge about a process. (Just and Carpenter, 1987) Both propositions and schemata are proposed for human use as well as for computer implementation.

On the other hand, mental models, which are working mental analogs of some process or situation, are considered to be held in the mind of a human only. An implementation on a computer would involve some other representation method. There is no intent to imply that a mental model must be encoded by a particular coding technique, such as an image, although images or pictures are frequently chosen to present mental models; the correspondence of the model's structure to the structure of the situation or event is the critical item and may be represented in a number of ways. (Johnson-Laird, 1983) In the case of comprehension theories, mental models are presented as a means of representing readers' conceptions of the situation (McNamara et al., 1991) and have been used in conjunction with propositional representations of textual expressions (van Dijk and Kintsch, 1983; Kintsch, 1988).

Brief synopses of several working models of text comprehension seem appropriate as an aid to pulling together the multiple processes that have been discussed in the sections on reading and text comprehension. A few examples will serve to illustrate the interaction of components and processes of reading comprehension and to show the state of the art in text understanding.

Comprehension-Integration Model

Kintsch's model of comprehension-integration is the latest in a series of models developed over a period of years in collaboration with the linguist, Teun van Dijk. (Kintsch and van Dijk, 1978; van Dijk and Kintsch, 1983; Kintsch, 1988) The model combines a construction process in which linguistic and world knowledge operate to produce a text base, which is then integrated into a coherent whole. Construction is essentially a bottom up process; integration, a top down application of knowledge through the mechanism of spreading activation.

Construction takes as input a short text, hand-coded into propositions, which are organized as an associative net in the model for knowledge representation. Construction processes, such as concept formation from the linguistic input (the propositions), elaboration of each conceptual element, generation of inferences (additional propositions), and weighting of associations, are done in a production system. A production system matches stored rules in the form of conditions and actions, for example, If p, then q, to representations of current situations, for example, p, producing as a response the action from a matched condition, for example, q. The construction process in the model operates in a loose manner, allowing generation of propositions that would not be appropriate to the context. The result of the construction process is

> . . . a network expressible as a connectivity matrix, consisting of all the lexical nodes accessed, all the propositions that have been formed, plus all the inferences and elaborations that were made at both the local and global level and their interconnections. (Kintsch, 1988, p. 168)

The integration process is organized in the connectionist manner and is used to eliminate those inconsistent components that were created during the construction process without regard to the discourse context. Integration is accomplished by spreading activation through the net. When the system stabilizes, there are some nodes in the network with low and some with high activation. The highly active nodes represent the discourse representation formed during the processing cycle. The process that is used to create this integrated comprehension product is constraint satisfaction. Hinton and Sejnowski describe this technique: "The network computes a 'good solution' to the problem by repeatedly updating the states of units that represent possible other parts of the structure until the network eventually settles into a stable state of activity that represents the solution" (Hinton and Sejnowski, 1986, p. 282). Also known as relaxation, the key concept is that data points, representing units of interest in the problem, jostle together, influencing and being influenced by each other, until the neighborhood settles upon a solution mutually acceptable to all its members. This technique operates without rules, a departure from the production system approach.

Kintsch supports the time course of the model processes with comparison to empirical observations from experiments concerning word identification and arithmetic word-problem understanding. Findings are "in good agreement" with the model for the activation of words. (Kintsch, 1988, p. 171) For the problem understanding experiments, the findings are not as clear cut. In brief, it seems that the model works on simple examples but has some trouble in more complicated situations. This is not entirely unexpected, since the model does specify a capacity limitation for its work buffer, the structure analogous to human working memory.

Just, Carpenter and Thibideau's READER Model

READER, the model proposed by Just, Carpenter and Thibedeau, is also the result of a number of years of development and research. (Just and Carpenter, 1980; Just and Thibedeau, 1984; Thibedeau, Just and Carpenter, 1982, cf. Just and Carpenter, 1987) READER is developed within a general architecture of thinking, entitled **C**ollaborative, **A**ctivation-based **P**roduction **S**ystem or CAPS. CAPS is the psychological environment in which READER is situated, presenting ". . . the natural landscape of the mind, consisting of storage resources (such as working memory) and processing characteristics (such as parallelism) that constrain the comprehension process" (Just and Carpenter, 1987, p. 272).

READER is a simulation that has the goal of presenting "how human readers comprehend a technical passage and, in particular, to account for the time they take to read successive words and phrases in the passage" (Just and Carpenter, 1987, p. 19). The model was to understand in the sense of ". . . extracting information from a text and being able to recall the passage approximately the way human readers did" (p. 263).

READER is given one passage as input and processes it word by word in a production system, updating its representation of phrase, sentence, text and situation as it goes. (pp. 19-20) Specific modules include word encoding, lexical access, finding unknown words, syntactic analysis, semantic analysis, referential processing and text-level processing that accommodates one schema for the passage that is used and a means of recall and forgetting. Knowledge in READER is expressed in propositional form, with each proposition having an associated activation level which is assessed and assigned by the comprehension process. When sufficient (in terms of the model's value system) supporting evidence is accumulated by a proposition, that proposition becomes part of the accepted interpretation of the text. (p.266)

A major design and performance constraint on these modules was the desire by the modelers to be true to the gaze duration data that had been collected from human readers reading the same passage. If a word required more processing time by humans, then the model was to give more processing time to the same word.

This model is a pure production system, and works both bottom up and top down. It reads its own text, in contrast to the comprehension-integration model, which required hand coded propositions. At the same time, READER relies upon a schema for interpretation of the relations between the propositions. Newell, addressing the question "Is psychology ready for unified theories?" calls the Just and Carpenter model a "harbinger. . . that makes the point well" (1990, p. 34). This is high praise indeed for a model that purports to exhibit processes for reading a passage but does not claim to be a theory of cognition in general.

Summary

The two models conclude the discussion of the state of knowledge of reading and text comprehension. Each model included component processes that had been recognized as integral parts of the ongoing reading and understanding process. Although neither model addressed feature detection, one did address perception at the word level; the other started its processing with hand coded propositions, more representative of sentence level processing. Both used production systems, the preferred choice of control processing for those who consider rules as the processing approach of readers. Notably, one model also included a relaxation technique, signaling that not all processes are considered amenable to rule formation but are better interpreted in a manner that allows data to interact in their drive toward a stable position. Both systems do attain a level of comprehension that mimics the level of a reader, albeit in very limited domains.

During reading and comprehension, the reader has been integrating the new information with current knowledge about the topic or even about the world in general. These cognitive processes rely upon two more basic cognitive processes, that of attention and of memory, which will be discussed in the next section.

Reading and text comprehension are vital components in the task of using public information to create private knowledge. Building an integrated understanding of a source is essential to determining its worth and relevance for the information problem at hand. In the study reported here, subjects are asked to use a number of sources, all of which require them to comprehend the material before they are able to use it for their own problem solving purpose. Comprehension of an information source is an essential ingredient to the construction of new knowledge since it provides building blocks for the new structure.

Attention and Memory

Cognitive psychology informally classifies mental processes as either lower or higher level processes. This classification depends not on the complexity or value of a process but rather on the fact that higher level processes -- for example, reasoning, problem solving, language comprehension and production-- rely upon the lower processes -- perception, attention, and memory. Typically, attention and memory are presented before treatment of processes which use them. In repositioning attention and memory after reading and text comprehension in this chapter, the intent was to provide a context for their review. Attention and memory are considered in relation to these processes, in keeping with the overall intention of focusing overviews on the specifics of this study.

Attention

Although the skill of attention pervades cognition, finding a definition for it is rare. William James expresses a sense of the phenomenon that is commonly used:

> Everyone knows what attention is. It is the taking possession of the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalisation, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others. (1890, pp. 403-404; cf. Eysenck and Keane, 1990, p. 97)

In spite of an intuitive agreement with James' meaning, attention has acquired more generality in psychology, and is taken ". . . to refer to all those aspects of human cognition that the subject can control . . . , and to all aspects of cognition having to do with limited resources or capacity, and methods of dealing with such constraints" (Shiffrin, 1988, p. 739)

Automatic versus Attentive Processes

In both connotations, attention contains a quality of excerpting or focusing. The ability to focus resources in a chosen direction, either perceptually or cognitively, encompasses capabilities of shiftability and divisibility as well as choice. The meshing of these qualities gives rise to concerns about switching, bottlenecks, dividing and focusing attention.

At the same time, the ability to consciously attend is balanced by an ability to automatically perform. Performing automatically implies fast, unconscious, unavoidable processes that use zero attention. (Eysenck and Keane, 1990, p. 118) It "just happens." Tasks which are fully automated in the strictest interpretation, that is, show no influence on other attention-demanding tasks or meet the criterion of unavoidabilility, comprise a small number of processes. Partially automated are more common than fully automated processes, and may become more automatic with practice, a fact that is attested to in numerous laboratory experiments concerning performance of two tasks simultaneously and in mundane activities such as typing or piano playing (Spelke, Hirst and Neisser, 1976; Shaffer, 1975; Allport, Antonis and Reynolds, 1972; all cf. Eysenck and Keane, 1990, pp. 112-113).

Both types of processing are apparent in real life experiences: the driver who finds him or herself at a frequently intended destination which was not the intended destination for the current trip is exhibiting automatic execution of a well-learned path; the driver who is locating an address in a strange town is exhibiting controlled or attended to processing of a new path.

Hasher and Zacks make the interesting observation that mental activities as well as physical ones may respond to practice and drill by developing an automaticity as do physical skills. (1979; cf. Best, 1992, p. 58) It seems, then, that practicing reading will help a reader to read more automatically, at least for non-problematic texts.

Another interesting observation follows from search studies, or those in which the detection or location of a signal is the task at hand. It seems that ". . . the search results demonstrate that attention itself can be automatized (stimuli can be trained to attract attention automatically)" (Shiffrin, 1988, p. 745).

Shiffrin identifies a dozen criteria that have been proposed over the years for differentiating automatic from attentive processes. He concludes that defining characteristics are not easily found, and those that are seem not to apply in a general way to all attention processes. (Shiffrin, 1988, p. 765)

One difference that seems of particular importance is that automaticity implies zero, or very minimal, use of the attentional resource while attending implies at least some level of resource use. Yet, individuals may attend to more than one stimulus at a time, as shown by a subject's ability to shadow a voice in one ear while also being presented with an auditory message in the other ear. (Cherry, 1953; cf. Best, 1992, p. 41) To shadow means to repeat aloud the message in the ear that is being attended to at the request of the investigator. In this paradigm, there is usually a different message being presented to the other ear, and a requirement to respond to some way to a particular stimulus in the second ear, for example, push a button upon hearing a high tone.

A number of theories have been proposed to cover this circumstance of divided attention. Divided attention is when one spreads attention over as many stimuli as possible. One group suggests that a filter imposes a bottleneck in the process of focusing attention. (Broadbent, 1958; Treisman, 1960; Deutsch and Deutsch, 1963; all cf. Best, 1992, pp. 42-50) Other researchers suggested that capacity is a limited resource which is applied to tasks until exhausted, and that since allocation of cognitive resources was under a person's control, shifting of the resource to an important stimulus was possible. (Kahneman, 1973; Johnston and Heinz, 1978; both cf. Best, 1992, p. 52) By not using a limited resource, an automated process is able to operate at the same time as another process, without the two interfering with each other. In either of the proposed explanations, attention is determined to be limited but under the influence of the individual.

A second criteria mentioned by Shiffrin was whether attentive processes may be equated with consciousness or awareness. This seems to be refuted by studies that show that a subject may be attending to some stimulus, called a prime, and still be unable to report it after being presented with a target. The priming effect that allows a faster reaction time to the target is considered to result from an automatic process since the prime cannot be recognized. (Shiffrin, 1988, p. 771) These priming effects are often interpreted as automatic spreading activation, a factor associated with creation and retrieval of knowledge.

Selective Attention

Selective attentive processes are those in which automatic processing plays an unimportant role. Higher cognitive processes use selective attention processes, particularly focused attention.

In focused attention, one attends to one stimulus and ignores all other inputs. (Shiffrin, 1988, p. 775) Reading more reasonably concerns focused attention. Most studies of focused attention use a visual search paradigm, wherein attention is to be directed toward a designated type of stimuli, and others are to be ignored. The results are that ". . . focusing upon location is fairly successful." and "Attention may be placed more or less at will in the visual field, but only in a contiguous spatial region (the 'spotlight') at any given time" (Shiffrin, 1988, p. 783).

Also of interest is the time needed to shift attention. In visual search studies, an attention shift that did not require an eye movement took less than 500 msecs; in a visual search which required a shift of attention upon successful completion of one task, approximately 400 msecs comprised the resulting shift time. (Shulman, Remington, and McLean, 1979; Sperling and Reeves, 1980; both cf. Shiffrin, 1988, pp. 786-787) Shifting attention is not immediate, but still is relatively quick.

In addition to attention, a second basic cognitive function underlies much of reading and text comprehension. That is the phenomenon of memory.

Memory

Memory is a core topic of cognitive psychology and includes creation and retrieval of memories, sometimes also called knowledge. Questions asked about memory have ranged from how much is remembered to what kind of things are remembered to how does memory change over time.

It is important to note a certain diversity in the references for the term memory. Some speak of memories and mean personal experiences, those that are autobiographical and sensitive to context of time and location (episodic memory); others speak of memory and mean compiled knowledge, that which is general and encyclopedic in nature, and organized by classes and abstract principles (semantic knowledge).

There is another distinction that is significant when looking at memory research: that between structure and process. The structural approach will focus on the organization of memories, their properties and relationships to one another; the process approach is concerned with operations that transform, abbreviate, or elaborate a memory. The distinction is only important because each pursues different hypotheses, thus expanding the knowledge base about memory.

Memory as Storage Components

A familiar view of memory is to think of it as a set of storage compartments, varying in capacity and duration, but serving the essential function of holding a memory. A memory is something that may be created, saved, stored, recalled and recognized. Under this interpretation, one would expect memory to have a location and therefore that it might be lost or blocked from retrieval.

A generic storage theory typically contains three types of memory: sensory, short term and long term. Sperling's work demonstrated a number of characteristics of the first of these. (Sperling, 1960, cf. Best, 1992, p. 131) Sensory storage is modality specific, i.e., there are different stores for vision, hearing, etc.; is large in capacity, being able to store all incoming stimuli briefly; operates very rapidly to produce a cognitive code; has very short duration, for example, in the neighborhood of a quarter of a second for visual stimuli; and is subject to decay as time passes. (Best, 1992, p. 130) Its function is to accept sensory stimuli for the cognizer; it is the cognizer who must allocate resources, i.e., consciously or not, to the code in order for it not to fade.

The distinction between the next two memory types, short and long term memory, has a long history and is well-accepted by psychologists. (Squires et al., 1993, p. 454) By short term memory is meant a component with limited capacity, which is verbally coded, is short (perhaps one half second) in duration, and decays. (Best, 1992, p.131) It is short term memory that is the more durable code produced from the sensory stimuli. Klatzy suggested a workbench analogy for short term memory to underline its limited capacity, its need for concentration by the individual, and its opportunity for elaboration or interpretation of code. (1980; cf. Best, 1992, p. 134)

Long term memory is what most lay persons mean when they say memory. It is an individual's long duration, large capacity repository for his or her memory and knowledge. Memories become part of long term memory via rehearsal, the transformation that maintains a code's vitality in short term memory while it builds up a code for long term memory.

Once stored in long term memory, a memory is considered permanent, although a thinker may encounter problems in retrieving it. (Best, 1992, p. 139) Squires et al. report that long term memory

> . . . is not a single entity but is composed of several different components, which are mediated by separate brain systems. . . The major distinction is between conscious memory for facts and events [declarative memory] and various forms of nonconscious memory, including skill and habit learning, simple classical conditioning, the phenomenon of priming, and other instances where memory is expressed through performance rather than by recollection [nondeclarative memory]. . . . (1993, p. 457)

They go on to characterize these two types of memory: declarative as fast, not always reliable, and flexible in its accessibility, whereas nondeclarative is described as slow, reliable and inflexible in that information is not readily expressed by a response system that was not involved in its learning. Further, episodic and semantic memories, mentioned earlier, are divisions within declarative memory. (pp. 458-459)

Memory storage systems have a processing cycle that starts input in the sensory store, transfers a code to short term memory as the result of applying resources to the sensory code, and transfers a code from short term memory by rehearsal to long term memory.

Memory as Levels of Processing

A less familiar approach to memory treats memory as the product of processing a stimulus in a variety of ways. Craik and Lockhart sought to replace the emphasis in research on structures and their capacities, duration, and forgetting mechanisms with a procedurally oriented approach that stressed the relation between different encoding operations and memory performance. (Craik and Lockhart, 1972) Their suggestion was that "the memory trace could be thought of simply as the record of those analyses that had been carried out primarily for the purposes of perception and comprehension and that deeper, more semantic, analyses yielded records that were more durable" (Lockhart and Craik, 1990, p. 88) Memory did not consist of a location nor did memorizing consist of a single operation; rather memories were traces produced as a person pursued various cognitive processes to perceive or comprehend or whatever. The persistence or durability of a memory depended upon the initial processing, with improved memory resulting from elaborative rehearsal, which involved a deeper semantic interaction with the material to be remembered. Different characteristics of memory such as capacity and duration were a consequence of resources and processing. For example, short term memory, called primary memory in this theory, is characterized as a limited resource and limited processing activity which represents a ". . . deployment of processing resources to various parts of the system, . . ." (Lockhart and Craik, 1990, p. 105).

The shift from structure to process in research was not unanimous, but it did move the emphasis from characteristics such as retention time, forgetting mechanisms and capacity to types of rehearsal, domains of processing levels, such as phonemic versus semantic, and context. (Lockhart and Craik, 1990, pp. 95-103)

Working Memory

A concept mentioned earlier was the idea of one memory acting as a workbench. The concept of working memory is directly related to this. Although concepts of short term memory and working memory have many areas of overlap, working memory is more functional in emphasis.

Working memory is accepted as a psychological mechanism with the role of a temporary processor of information from the external world and from memory. As such, it is a process involved in numerous cognitive activities such as language, reasoning, and long term learning. (Gathercole and Baddeley, 1993, p. 2) Working memory is one of the primary tools that psychologists propose for depicting how the work of cognition is done. Working memory, as a mechanism, is implicated in all the higher cognitive processes because it is seen as a foundational process.

A model of working memory integrated structures and processing into "a common system . . .[which] is limited in capacity, and should operate across a range of tasks involving different processing codes and different input modalities" (Baddeley and Hitch, 1974; Baddeley, 1986, pp. 34-35).

The model consisted of three parts: a central executive which regulates the flow of information within working memory and to and from other memory systems; and two specialized systems for processing of material within particular domains, the phonologic loop (sometimes called the articulatory loop) in the domain of verbal information and the visuo-spatial sketchpad for spatial and visual material. (Gathercole and Baddeley, 1993, p. 4) It is the central executive which drives the entire system, but much of the specialized processing of verbal or visual material is done in the specialized processors. The phonologic loop consists of a store for the phonologic code of verbal material and the specialized process of articulatory rehearsal to refresh the code. It is also the process which recodes nonphonologic inputs such as words or pictures into a phonologic representation. (Gathercole and Baddeley, 1993, p. 8) The visuo-spatial sketchpad performs similar functions for visual or spatial information. (Gathercole and Baddeley, 1993, p. 17)

Other models of working memory were also proposed. The change in Daneman and Tardif's suggestion was to emphasize specialized processors, particularly one for language. By using three measures of working memory, particularized for verbal, math and spatial materials, they found ". . . considerable support for a language-specific system or at least one that is specialized for manipulating and representing symbolic information" (Daneman and Tardif, 1987; cf. Daneman, 1987, p. 74). Lockhart and Craik found this version more compatible with their levels of processing approach because of its emphasis upon processing using multiple computational abilities with various types of information. (Lockhart and Craik, 1990, p.106)

Memory, Reading and Text Comprehension

The relationship of memory to reading and comprehension has been explored over a number of years. Historically, recall of read material was a favorite interest. Notable is Bartlett's *Remembering* published in 1932. In a series of studies, Bartlett attempted to determine how much and for how long read material would be remembered. He asked readers to read a passage; then, at several different times after reading, they were asked to write as near a verbatim reproduction of the passage as they could. Bartlett was interested in memory, or more accurately, remembering. He found that his method of repeated reproduction allowed him to concentrate on the errors made in remembering a story. The story, the famous "The War of the Ghosts" story, was a North American folk-tale, differing substantially from the culture and society of the subjects.

Bartlett found that subjects' were reconstructing the story, not remembering it verbatim. The reconstructed versions showed changes that converted the unfamiliar story features into those consistent with the knowledge and background of the reader. (Bartlett, 1932) Bartlett goes on to discuss the concept of schema, a prime candidate for organizing conceptual knowledge; the point is that the long term memory of the read story was not verbatim, but was in terms of main ideas and expected behavior.

More recently, Sachs (1967) has shown that ". . . verbatim recall of printed text was accurate only if tested immediately, and deteriorated substantially when even one sentence was interpolated between presentation and test" (Sachs, 1967; cf. Baddeley, 1986, p. 189). Jarvella (1971) showed that accurate verbal memory is for a single clause, usually the latest one read. (cf. Baddeley, 1986, p. 189) The consensus of research is that long term memory of text is not of the surface sentence but rather of the underlying structure of concepts and relationships, that is the meaning.

Baddeley comments

> While reading and comprehension do involve memory, long-term episodic memory is not essential to reading since grossly amnesic patients can typically read and comprehend very adequately, although they may well not be able to recall what they have read after a brief delay" (Baddeley, 1986, p. 170)

Remembering a text verbatim would be an example of episodic long term memory. Since most readers do not create this kind of long term memory for the texts they do read, attention shifts to the exploration of the process of reading and its relation to memory. There has been a strong interest in the actual construction step, usually couched in terms of the contributions of short term or working memory to reading. (Daneman, 1987; Glanzer, Fischer and Dorfman, 1984; Baddeley, 1986; Glanzer and Nolan, 1986) In most cases, the interest is in the fast and automatic process of reading and text comprehension.

For example, short term storage is examined in its role in this process. In a series of studies, Glanzer and Nolan examined the role of working memory using normal text. They were able to formulate a theory of reading that included the use of memory mechanisms and concepts. In short, the theory posits short term storage as a mechanism that formulates and relates the themes and topics of each presented sentence. Each sentence is read, and its integration is mediated by short term storage. Short term storage contains the last one or two sentences verbatim as read or heard. Since they have been related to the underlying representation, they are able to elicit corresponding parts of the underlying representation, bringing it into contact with the information in the succeeding sentence and to aid in the linkage process supported by cohesion devices. (Glanzer and Nolan, 1986)

In other work, Daneman and Carpenter (1980) argue that the essence of working memory is its division of capacity into storage and process. They propose that storage is the left over capacity not used by a reader to process the text. By measuring a reader's ability to remember sentence-final words from differing size sets of unrelated sentences which they have read aloud, Daneman and Carpenter (1980) claimed to have ". . . indirect[ly] measure[d] the efficiency with which it [the central executive of working memory] could execute the sentence comprehension processes" (cf. Daneman, 1987, p. 62). This leads to the conclusion, based on differential performance of readers with reading spans of two or three sentence-final words as compared to readers with four or five, that "The capacity of the central executive seemed to play a particularly important role in the processes that integrate successive ideas in text" (Daneman, 1987, p. 62).

This short review indicates that there is definite involvement of short term or working memory in reading and comprehending. In particular, it seems that there is consensus that the latest text read is likely to be in short term memory and available for processing. As will be shown later, Ericsson and Simon rely upon this involvement to support their theory of verbal reports as data.

Summary

Attention and memory are deeply implicated in reading and comprehending. In real-time reading, both long term memory in terms of a reader's semantic knowledge and short term or working memory in terms of conscious processing of currently attended stimuli are involved. To read and to comprehend depend upon the interaction of knowledge and cognitive procedures.

In this study, attention and memory play an important role in creating data that are collected. It is by reporting the contents of short term memory that verbal protocols are created, as will be discussed in more detail in Chapter Three. At the same time, it is problem solvers' semantic memories that are implicated in many of their activities with the information. Attention to the task at hand is necessary for focused progress; memory is needed for both for knowledge creation and for its retention.

Reading to Write

The preceding sections chronicle the dominant processes of building personal knowledge. For most information problems it is not sufficient, however, to just understand information or even to construct personal knowledge about it. Typically, some application of the knowledge is intended.

Because this study emphasizes the activity of constructing personal knowledge and thus focuses attention on constructing knowledge from information that is read, the application (the creation of the actual written solution) is considered an ancillary undertaking. Although not at the center of attention, the application task may affect the activity for which personal knowledge is needed; thus, an overview of information about writing is needed, but will be restricted to information on the narrower area of reading to write.

Studies have addressed reading with purposes such as learning (de Beaugrande, 1984); studying (Anderson and Armbruster, 1984); and doing (Sticht, 1977; cf. Flower et al., 1990). Writing and reading have been discussed as two similar constructive activities which use many of the same cognitive processes. Some search for ". . . cognitive universals of reading and writing" (Kucer, 1985); others, ". . . the reading-writing relationships" (Tierney and Shanahan, 1991); and yet others are looking for ". . . the complex processes involved in readers' and writers' construction of textual meaning" (Spivey, 1990).

Flower et al. (1990) considered reading to write a goal directed activity involving both reader and writer in processes of creating individual representations of the text. They found a number of observations about writing for a class assignment and using written sources. Significantly, the task was seen differently by different students, even though this was a common academic task. Because the differences were tacit, thus not shared with the instructor, conflicts in understanding the task interfered with task success. Even when task was clear to both student and instructor, students were not always able to do what they planned and what was needed. Flower says "Task representation may play a far larger role in a writer's performance -- and success in school -- than we have recognized; . . . " (Flower et al., 1990, p. 21-22). She goes on to sum up the overall finding of this series of studies: "

> The knowledge writers need, as we came to see it, was best described as *strategic* knowledge. It involves reading a situation and setting appropriate *goals*, having the *knowledge* and *strategies* to meet one's own goals, and finally, having the metaknowledge or *awareness* to reflect on both goals and strategies. (Flower et al., 1990, p. 23, emphasis in original)

Although Flower et al. cast their monograph in terms of reading to write, their main focus is the writing process. Other work addresses the reading as well as the writing portions of the task .

An example is the work on processes of reading and writing contained in the studies on composing from sources, another term used for reading to write. Instances of this class are specifically those in which

". . . writers draw directly from other texts, instances in which the prior texts are knowable and traceable and when those prior texts might be compared with the new texts created from them" (Spivey, 1990, p. 257). This is a hybrid area, in which both reading and composing are examined because the combination represents a real world activity of doing something with the knowledge gained. Spivey suggests that organizing, selecting and connecting are the three prime operations for constructing meaning from text, either as reader or writer. In conclusion she says,

> I have portrayed acts of composing from sources as a kind of interplay between what sources offer writers and what writers, drawing on their knowledge of various types, can do to use and transform those texts as they construct their own meaning. . . .What we have in composing from sources is a set of choices that writers can make about how those sources might be used. (Spivey, 1990, p. 281-281)

Again, the viewpoint of this work seems to be that of the writer, even though the discussion concerns both reading and writing as meaning constructing activities. Emphasis is on text composition, as signaled by the choice of wording for the task.

McGinley also addresses the mix of processes displayed while composing from sources. (McGinley, 1992) He codes readers' verbal protocols, which have been separated into individual communication units consisting of a main clause or a subordinate clause, for three types of information: time it occurred in task, which reading or writing activity it occurred in, and the reasoning operation that it embodied. Using these, he presents a time course display that shows patterns of activity and reasoning across the task. Among the major findings is that composing from sources is not a strictly linear process that moves from reading to writing; reading occurred throughout the task period, although what was being read was not necessarily the same. For example, during the first quarter of the session, source texts were the reading objects, whereas during the second and later quarters, notes and drafts made up the reading materials. (McGinley, 1992, p. 233).

Using a set of categories from Langer, McGinley also looked at the reasoning operations of his readers. (1986, cf. McGinley, 1992, p. 245). During all quarters of task activities, they favored using schema, an operation that reflected the subjects use of knowledge to formulate, evaluate or explain his or her ideas; metacommenting, in which comments about the subjects use or nonuse of structural or content information were made; and questioning, which indicate uncertainties subjects may have had.

McGinley focuses on the behavior over time of the reader/writer. He does examine the types of reasoning exhibited but does not consider the textual interactions per se.

Summary

The importance of task may not be overlooked in any study of reading behavior. This section has illustrated the cognitive processes that are involved in using written texts as sources for creating a personal written text. An important observation is the mix of linear and nonlinear processes that a writer uses.

Although the emphasis in this study is upon the actual reading and use of information to create personal knowledge, the study is cast in terms of using written public sources to produce a written response. This is the same task examined in reading-to-write or composing from sources studies. Although the study concentrates on one component of reading-to-write, reviewing work on the processes in the task gives an essential picture of the entire process.

Conclusion

This chapter has presented detailed information about the processes of the study task in order to foster an understanding of the state of knowledge about personal knowledge construction. Beginning with the first perception of the visual signal, the processes employed to decipher words, the fixating of almost all words by the eye, and the integrative processes that make syntactic and semantic sense of a sentence, the reader proceeds to comprehend the textual material through constructive processes using both information from the text and from the world knowledge that he or she has. It becomes obvious that the reader has limited resources with which to complete this process, and must attend to the allocation of those resources for successful reading. Further, the effect of context, including the task for which the information is being sought, has been demonstrated as relevant to ongoing processes. Notably, the reader's task is not accomplished in a straight line mode, but exhibits both linear and nonlinear selections of activities.

For all of the information that the individual processes supply, no one of them provides a total picture. Looking at the combination of processes gives the best overall view, while pointing up topics that may respond to further study. In particular, although effort has been spent on reading and understanding a text, and separately on using the understanding that is constructed to complete a task, the actual on-line or real-time interactions of the reader and the material are not delineated in context. It is this behavior of interacting with information that makes up constructing personal knowledge and is at the heart of solving an information problem. An exploration of these interactions may lead to a better understanding of the impinging influences and the process.

CHAPTER 3. METHODOLOGY

INTRODUCTION

The purpose of this chapter is to describe the methodological choices that were made for the study. In keeping with the philosophical stance articulated in Chapter One for information and user, the choices are biased toward the active, constructivist nature of humans. For research inquiries this translates into a naturalistic, qualitative approach.

The naturalistic position is described by Lincoln and Guba (1985) as an alternative to positivist inquiry. Five basic axioms delineate differences between the two paradigms. Briefly, these axioms concern the nature of reality, the relationship of knower to the known, the possibility of generalization, the possibility of causal linkages, and the role of values.

Traditional or positivist inquiry considers that reality exists objectively and independently of a perceiver and that the objective is to construct generalizations that are context free and reflect a cause and effect linkage. (Lincloln and Guba, 1985, p. 37)

Naturalistic inquiry takes the position that realities are constructed interactively and holistically by a knower and are inseparable from time and context, since all entities are in a state of mutual simultaneous shaping. Because working hypotheses are context bound, it is impossible to distinguish causes from effects. (Lincloln and Guba, 1985, p. 37)

These axiom values underlie the research design and implementation choices that are made by a researcher. Choice of the alternative or naturalistic inquiry paradigm signals a concern for a holistic, situated event, with interpretation tied to the entities and their mutual interaction. The focus is on individuals as necessary interacting parts of the world influencing and being influenced by the object of research interest.

Methodological choices were constrained by three general factors: (1) the study's broad objective of describing, (2) its specific objectives of identifying structures and relationships, and (3) pragmatic influences of time and resources.

CHOICES

The first choice was that of the overall purpose of the study. The choice for this study was to build a description of the phenomenon of interacting with information. An exploration to discover components of the phenomenon was indicated by the scant descriptions available in the literature. As shown in Chapter Two, research on the topic does exist in a number of disciplines. Closest in topic are the studies of reading-to-write which treat interactions either as a series of processes, (for example, McGinley's work) or as an exercise in discourse analysis (as in Spivey's research). The interactions of text and problem solver are addressed separately.

The researcher elected to return to basics and collect and examine examples of the phenomenon from the bottom up. This is an exploratory stance, with the primary purpose of describing what is happening, not why it happens.

In support of this stance, several other choices were made. One concerned the use to be made of the data that was collected. In general, the choice is between using data deductively to go from a general conclusion (the hypothesis) to verification of occurrence in specific instances (the sample) versus using data inductively to go from individual cases (the data) to the derivation of conclusions (the categories). (Lincoln and Guba, 1985, p. 333) If data are to be treated deductively, an hypothesis would become a driving factor in defining which data are to be collected. One identifies in advance which type of data is needed and designs a study to collect that specific set of data. The collected data then are used to evaluate the hypothesis.

If data are to be treated inductively, one plans to derive categories and relationships from the data as they exist in the event itself. The data are to be the source of categories, produced by examination and application of knowledge of the researcher. No hypothesis is overtly suggested prior to data collection. The purpose is to leave open the discovery of the possible conclusions or categories that are inherent in the data. It is important to recognize that it is probably impossible to undertake a study of an area of interest without some underlying assumptions and expectations. The researcher should strive to be aware of this limitation and to compensate for it.

The choice for this study was to use data inductively. The collection of thick data was planned to foster collection of components of the event with as little pre-winnowing or pre-judging of elements to be gathered as possible. "Thick data" describes the assembling and capture of as many as possible of the elements in a situation as opposed to the collection of "thin data," a term used to describe a selection of constrained and pre-chosen responses. Thick data is a term based on the idea of "thick description" used by the anthropologist Geertz to emphasize detailed culturally interpretable description of an action or event. (Mellon, 1990, pp. 11-12) It captures more of the components of the event, and thus preserves for the investigator a fuller complement of its elements. Thick data supports clarification of a term by aiding in picking out some of the types that might exist for that concept.

Not only is the data used inductively, but also the units of analysis are abstracted from the stream of data inductively as well. Rather than approach the phenomenon with predefined units which will be systematically counted, a technique known as enumeration, the stream of data is examined for self-defining units, a process called construction. (Lincoln and Guba, 1985, p. 334) The stream of data is parsed based on its contents rather than on *a priori* event definitions. This study relied upon examination of the data to identify the units that represented the event most naturally.

A fourth dimension addresses the source of derivation of categories. Lincoln and Guba (1985) quote Goetz and LeCompte (1981) on this issue:

> The goal [of subjective data analysis] is *to reconstruct the categories used by subjects to conceptualize their own experiences and world view*. This contrasts with an objective approach, *which applies conceptual categories and explanatory relationships, readily visible to external observers*, to the analysis of unique populations. (p. 334, emphasis in original)

The issue is not the objectivity or subjectivity of the researcher but rather the researcher's commitment to the manner in which categories are discovered, with a choice to prefer the terms brought to the researcher by the subjects. It is part of the inductive nature of the investigation to use the subjects' terms to reflect the phenomenon thus providing a truer reflection of the intricacies of the event including its human interlocutor.

GROUNDED THEORY

The basic choices identified above are neatly bound in an approach called by Glaser and Strauss (1967) "the discovery of grounded theory." According to the authors, discovery of theory from data is a disciplined, systematic enterprise that uses the general strategy of comparative analysis to generate from a data stream categories and relationships appropriate to the phenomenon under study. Within the emphasis on theory generation is also the closely related emphasis on the primacy of data in the generation process. It is the immersion of the researcher in the data and the researcher's openness to the natural categories and relationships that exist for the subjects that produces the grounding of the theory, which is a hallmark of this approach. This openness reflects in the developing theory when the parsing of the data stream is done in terms of events significant within the stream, when the data are the determiners of the categories found in the theory, and when the use of subjects' terms for categories and relationships is evident.

Grounded theory supplies an operational approach as well as a theoretical basis for developing theory. Through a series of specific choices, a researcher guides the study toward its purpose. Individual selections produce the requisite data and drive the appropriate analyses, but it is the totality of choices that gives the study its solidity. The specific choices made for this study are described below.

SPECIFIC CHOICES

Within the framework of basic choices and grounded theory, specific choices were made that comprised the study's data collection and analysis methodology.

Task

Although the scenario used in the study has been discussed in terms of its structure, the reasons behind the choice have not been given overtly. The Sammy Student scenario, related in Chapter One, is the common one of a student using sources to write a paper for class.

Essentially, the choice to examine the Sammy Student scenario was based on Simon and Siklossy's advice, quoted in Streatfield (1983):

> . . . the method that has proved most fruitful in research on complex information processing: to investigate a phenomenon, choose a task domain where the phenomenon is prominent and design an information processing system that is able to perform tasks from that domain. (p. 225)

The Sammy Student task represents an obvious and ubiquitous use of information to solve an information problem. A primary goal of education is to develop in learners the ability to solve just such problems as are represented by writing a paper on a topic about which little was previously known. Developing a paper from external sources of information is a prominent task in many learning situations.

In this study two student assignments, differing in topic but retaining the same task requirements, were used. Written problem statements were presented to the participants. They are shown below:

> (1) Using the material provided, write a half page or so about the important capabilities for software which is used to create a back-of-the-book index.
>
> (2) Using the material provided, write a half page or so about the development of children's and young adult's non-fiction as literary art.

This version of the student scenario falls in the category of externally generated information problems, that is, one generated by someone other than the problem solver. An attempt was made to acquire volunteers with some interest in the topic by using material related to a course that a participant was taking. Problem One was aimed at enticing volunteers from an indexing and abstracting course, whereas Problem Two was directed toward students in a children's literature course.

Volunteer interest was sought to foster the naturalness of the task. A task generated by an outside agency may not rely upon personal interest as its motivation for solution. Although a certain level of personal involvement becomes necessary to identify the specific knowledge gap of the problem solver, the underlying motivation may be another factor such as job retention. In this study, the underlying motivation was not one of personal interest. Therefore use of information problems related to topics of interest to the participant was considered desirable to aid in presenting a situation which would foster the internalization and development of the gap as easily as possible. At the level of interacting with information, the task seemed capable of eliciting natural behavior in the use of information to solve an information problem.

The Sammy Student task presents several logistical advantages from the viewpoint of the information problem solving investigator. First, comparable tasks serve as the source of the information problem for participants. Although the topic of the information problem differs for each participant in the solving portion of the study, they all share essentially the same initiating task assignment. Secondly, the investigator may provide the same external materials for each problem to participants involved with that problem, providing a common base of information. Thirdly, the researcher had access to students and an appropriate setting for data collection (discussed below).

Two problems differing only in topic were used in order to introduce a minimum of diversity in the phenomenon examples. Because the intent is to identify basic components and relationships, the goal was to collect examples of a similar nature, but which included different topics to preclude unknown influence from the topic itself.

Data Collection

The detailed choices of subjects, materials, setting, equipment and data to be collected comprise the grist of the study's data collection design.

Subjects

All subjects were volunteers from among graduate students enrolled in courses in the School of Library and Information Studies at the University of Hawai'i. They were unpaid but did receive a small gift of appreciation upon completion of data collection. There were 19 participants for whom data was collected. One participant chose to withdraw within the first few minutes of the session, and was eliminated from further consideration. Nine participants were given Problem One and nine, Problem Two.

All participants would be considered experts in this kind of problem solving. It is difficult to imagine a graduate student who has not written a number of term papers, using written material found through searches of literatures. Although it is probably not typical that they would have had a complete search done for them with the results delivered in a neat package by an intermediary, it is likely that they would have experienced some occasions on which they asked for and received some assistance from a librarian or instructor in finding materials that were considered topically relevant to a task problem.

Materials

The materials that were available to each participant included a written statement of either Problem One or Problem Two, information sources about the topic chosen by the researcher, pen, and plain lined paper.

The investigator provided seven documents for each problem. Each document was judged topically relevant for the problem it supported by four independent judges, drawn from the faculty of the School of Library and Information Studies. Using a scale ranging from 1 for not relevant to 5 for relevant, the four judges assigned scores to each document. From a total of 20 possible points, the lowest score for any document was 13; five documents achieved the highest possible score of 20. The average for the set related to Problem One was 16.4, with the lowest score of a document in the set being 13. The average for the set for Problem Two was 19.1, with the lowest score being 18.

Each document was reproduced on different colored paper and given a number to facilitate identification during data analysis. Documents ranged in length from one page to twelve pages. Each subject was provided a personal set of documents.

Setting

Setting is considered by many to be an integral part of a naturalistic inquiry. Indeed, studying the phenomenon in its natural setting seems to be one of the defining characteristics for a naturalistic inquiry. (Lincoln and Guba, 1985, p. 39) Because of its centrality to the naturalistic paradigm, a more thorough discussion of setting is required than would be needed for a traditionally based study.

The underlying purpose for doing a study in a natural setting is based on the view that context is a vital part of an individual's reality. Including context as part of the reality being studied enhances understanding, gives less opportunity for dismissal of mutually interacting influences, and permits value structures derived from context to exercise their proper determining roles. The question arises as to the naturalness of the chosen setting for the task that was being performed.

Choice of setting was made by the investigator, thus precluding choice by each individual participant. The setting was a small conference room in the School of Library and Information Studies that was furnished with a standard table and chair for the participant. In addition, the room also held a visible video camera and a separate table and chair for the investigator who was seated behind and out of direct sight of the participant during a session.

The task of interacting with information is done in many types of locations. The setting chosen for the study is a common, although admittedly not universal, setting for someone using a number of documents to prepare a written response to an information problem. The subjects are accustomed to pursuing their information tasks in the school facilities. The existence of the camera and researcher in the setting was unnatural but did not appear to affect partcipants once the session was underway. The phenomenon of interest--interacting with information-- is considered, therefore, to be performed within a reasonably natural setting, even if the specific setting is not personally chosen by the participant. That is, the setting in which the participants actually performed the problem solving was natural without being individually personal for each participant.

Use of a common facility for the study was advantageous logistically. A camera could be located in the best place, quiet surroundings could be chosen, and distractions could be controlled. Although these factors are convenient and useful for simplifying the logistics of the study, they are also reasonably similar to an actual setting (with the exception of the video camera) that a participant might establish for writing a paper.

Data To Be Collected

A variety of data were collected for this study. These were simultaneous verbal reports, actions, an evaluation by each participant of the usefulness of each information source and a written solution to the information problem.

Simultaneous Verbal Reports

The primary data collected were the simultaneous or concurrent verbal reports of subjects as they used the information sources to solve the information problem. Asking participants to speak their thoughts aloud is called the thinking out loud method; it is called simultaneous or concurrent reporting when subjects think aloud during the performance of the phenomenon under study.

As Olsen and Mack point out,

> But the TOL [thinking out loud] task is best used to study the higher level processes in reading: the inferences, predictions, schema elaborations, and other complex cognitions that occur as part of skilled reading. We assume these processes are most available to consciousness as the reader reads. The output of these processes are verbal, slow to arise, and samples of them are sufficient for the investigator to infer what must have transpired. In general, . . . the TOL method is specialized for the study of thinking. (1984, p. 255)

Because the study objective was to describe the phenomenon, thick data reflecting its process and components were required. Thinking out loud during performance of the phenomenon provides a running stream of the contents of short term memory. Kintsch characterizes the procedure:

> Subjects who are asked to give think-aloud protocols while reading typically read aloud for a while the text they are given but then interrupt themselves (e.g., when they encounter a comprehension breakdown) and comment on what they are doing. They are problem solving at this point, making inferences, retrieving appropriate knowledge, and so on. But even when they are just reading aloud, having nothing to say beyond what they are reading, they are activating knowledge, producing low-level inferences. (1992, p. 151)

Participants are expected to report what they are thinking, but are not expected to explain or give reasons for what they are thinking. This thick stream of data becomes input to the investigator's analysis, where the explanations or reasons are developed. Ericsson and Simon (1984) neatly summarize the rationale behind using verbal reports:

> Human subjects are not schizophrenic creatures who produce a stream of words, parallel but irrelevant to the cognitive task they are performing. On the contrary, their thinking aloud protocols and retrospective reports can reveal in remarkable detail what information they are attending to while performing their tasks, and by revealing this information, can provide an orderly picture of the exact way in which the tasks are being performed; the strategies employed, the inferences drawn from information, the accessing of memory by recognition. (p. 220)

History

Ericsson and Simon (1984) summarize a long history of using verbalization of participants to uncover internal, non-observable processing. (pp. 48-62) An early version of this data collection method, called naive introspection, became suspect as being a mixture of speculation and self-observations, and thus not conforming to scientific standards for indisputable observations.

Analytic introspection, which followed, was more than mere observation of one's own cognitive process; it was the trained observation and reporting of complex phenomenon according to an established set of categories and procedures. It was attacked by the behaviorists on the grounds of lack of reproducibility; prior knowledge of the hypothesis under study by the subjects, precluding a truly unbiased report; and difficulty in communicating meaning. In all, it was argued that introspective reports were unreliable in the scientific sense.

Watson, the archetypical behaviorist, distinguished between analytic introspection, verbal questioning of a subject, and thinking aloud. Although not convinced of the scientific soundness of the first two, he considered thinking aloud as the "overt verbalizations" which correspond to the normally covert thought activity. (Ericsson and Simon, p. 58-59) Little work was done with think aloud during the behaviorist period because of their preference for overt performance rather than mediating processes, which preference was reflected in the assumption that introspective reports, even if correct and informative, were unnecessary and were more appropriately replaced by behavioral measures.

Ericsson and Simon's Model of Verbalization

During more recent times, the cognitive paradigm has relied upon a more constrained version of think aloud. Ericsson and Simon's (1984) is the most commonly used model. The emphasis is upon direct expression of a thought during the process itself. This method became most useful when verbalized information was given a theoretical meaning by being embedded in a formal model of thought processes. (p. 61)

In brief, their model of verbalization holds that verbalizable cognitions can be described as states that correspond to the contents of short term memory, representing the information that is in the focus of attention. Vocalization is a verbal encoding of the information; verbalization processes are initiated as information is heeded and represent a direct encoding of the heeded thought while reflecting its structure. Articulation identifies units and pauses, while hesitations are used to divide the verbalizations into integrated cognitive structures. (pp. 221-225) Heeded information is both the output of a process and the input to another process, and is the source of data about the structure of the process being executed (pp. 242-243) Thinking aloud reports consist mostly of verbalizations of heeded information. (p. 258) Thoughts that are automatic and thus not in attention will not be reported. The model accommodates thoughts that arise from perception, generation from a cognitive process or recall from long term memory.

Current Concerns

This method is not without its points of concern. The main points of concern are (1) effect of verbalization argument, which asks if verbalizing concurrently, or knowing that a retrospective report is to be collected, changes the task performance; (2) the incompleteness argument that says that subjects fail to verbalize a considerable portion of information in short term memory; and (3) the irrelevancy argument that information reported is parallel to, but independent of, the thought process, thus being irrelevant to the thought process. Each concern is discussed below in relation to its effect on the reports collected for this study.

Effect of Verbalization. This concern is addressed in detail. Ericsson and Simon describe three levels at which a person may verbalize his or her thoughts. Level 1 is simple vocalization of covert articulatory or oral encodings, either directed inward to self or outward to others. Level 2 is description of thought content, which labels thought content held in some compressed format or in a format not usually verbal, such as information about odors. Level 3 is explanation of thought content or processes, which recodes but also links information in short term memory with previously acquired information. Ericsson and Simon (1984) determine that "When the instructional procedures conformed to our notion of Level 1 or Level 2 verbalization, the studies gave no evidence that verbalization changes the course or structure of the thought processes" (p. 106).

Data collection for the two problems used slightly different thinking out loud instructions. For the first collection, this instruction was given:

> Please think aloud as you do this problem. That is, you are to say out loud whatever is in your mind as you read the material and think about this problem. The purpose of thinking aloud is to record from your words what is going through your mind. Your spoken thoughts are the data

> which I will use in my study. You may find that you read some or none of the documents aloud as you do this. Either is okay. Work as naturally as possible, while saying aloud your thoughts.
>
> I will be here to monitor the equipment and if needed, to remind you to continue saying aloud what you are thinking.

For the second data collection, the thinking aloud instruction was simplified:

> Please say aloud whatever is in your mind as you do this problem. I will be here to monitor the equipment. I may remind you to continue saying aloud what you are thinking.

If reminders to continue verbalizing were needed, they were phrased in a neutral manner that asked the participant to talk out loud, or to keep talking. Both instructions elicited verbalizations of thoughts at Level 1 and perhaps at Level 2. The "whatever is in your mind" might be intepreted as requesting recoding of non-verbal contents of short term memory. The emphasis is placed upon Level 1 data in the basic instruction to "think aloud" and in the phrases which request that the participant try "saying aloud your thoughts" as work proceeds and "to continue saying aloud what you are thinking" if reminded to think aloud.

Completeness of Reports. This concern deals with the probability that processes underlying thought may be unconscious and not available for reporting. Although participants could not report these processes, they frequently report the results of a process. One notable example of this is the process of recognition. When one retrieves something from long term memory via the use of a subset of the characteristics of that something, one is recognizing it. Recognition, the product, is reported, but its steps remain unavailable to the awareness of the recognizer.

The task used in the study involves myriad processes of recognition that will be outside conscious awareness. Reading is a complex of these processes, ranging from recognition of words from its features to recognition of lexical items. But awareness of the inputs and outputs of the many processes of reading and writing allows the reporting of the occurrence and duration of such processes. Some incompleteness of reporting will occur.

Irrelevance of Report to Actual Thought Process. This concern deals with the possibility that verbal reports are epiphenomena and do not truly represent thought. This argument is countered by subjecting verbalizations to three tests or criteria for pertinence to the thought process. The first test is one of relevance, in which the thoughts verbalized should be relevant to the task being done. The second is consistency, in which a thought verbalized should be related logically to those immediately preceding it. The third is memory, in which evidence can be found that a subset of information heeded during a task will be remembered, and will be available for recall or recognition. (Ericsson and Simon, 1984, p. 171) Ericsson and Simon (1984) sum up their effort to consider this concern:

> We have assembled all of the experimental evidence we could find that bears on this issue. With great consistency, this evidence demonstrates that verbal data are not in the least epiphenomenal but instead are highly pertinent to and informative about subjects' cognitive processes and memory structure. (p. 220)

Action or Motor Processes

In addition to collecting verbal reports, the actions of the participant were also recorded. Actions or motor processes also provide information about the problem solving process. This protocol was collected as a supplement to the verbal report. Participants were given more than one document to use as they performed their task. It was considered that asking the participant to identify the document in use would interfere with the normal process of using information. The use of documents printed on colored paper allowed the investigator to identify the document in use without introducing an unusual element to the task. In addition, actions such as picking up a different document signal problem solving processes that may be unrecorded in the verbal report.

Evaluation of Usefulness of a Document

The third type of data that was collected was an evaluation of the usefulness of each of the information sources by the participant. The purpose was to obtain a formal evaluation by information problem solvers of the usefulness of the information sources to them in their information problem solving, since all the sources were topically related. The evaluation form requested a rating on a five point scale, of 1 for not useful and 5 for very useful.

Procedure

Collecting data was done systematically for each participant. The procedure included introduction of the task, the topic, and the think aloud method. Practice was given in thinking aloud, since this is not a universal feature of thinking. A checklist was used for each participant in order to insure that nothing was skipped or altered.

Steps in the procedure were as follows:

1. Participants were advised of their rights and were asked to sign a consent form. No participant refused.

2. The practice problems were done after a short introduction to the method and idea of thinking aloud. Practice consisted of two brief exercises during which the participant was to think aloud: one exercise was to multiply two numbers, and the second was to use a brief information source to respond to an externally posed information question. The second practice problem is very similar to the task that the participant performs. Time spent on this thinking aloud practice was usually less than five minutes. The practice exercises were not recorded.

3. The video camera was turned on, the audio microphone was attached to the participant, and the investigator recorded the participant's name and identification number.

4. The researcher handed the participant the problem statement and personal copies of the information sources. The instructions were read to the participant. Instructions included a restatement of the problem for the individual participant, a statement that the participant could write on the materials if he or she wished, one of the think aloud instructions as shown above, a statement that the colors (and numbers) on the documents were not significant and were there to assist in coding the data, a request to work at his or her own pace and to notify the

researcher upon completion. The final instruction was to ask if the participant had any questions before starting.

5. The researcher then asked the participant to "State in your own words your information need as you understand it at this time" and to begin problem solving.

6. The participant proceeded to use materials available. The camera recorded the session. The researcher reminded the participant to think aloud if necessary, and also monitored the operation of the video equipment.

7. Upon notification by the participant of completion and with the camera still recording, the researcher asked the participant:

a. State in your own words your information problem as you understand it at this time.

b. Are you satisfied with your solution?

1) If yes, what is it that makes you satisfied with the answer?

2) If no, what is it that leaves you unsatisfied with the answer?

8. After turning the camera off, the researcher gave the participant the document evaluation form and requested that each document be evaluated on the usefulness scale.

9. The participant was asked to not discuss the experiment with other classmates.

10. The researcher thanked the participant and gave each a small token of appreciation for participating (a University of Hawai'i logo pencil and a small "post-it" notepad).

Data Analysis

After collection of all subjects' protocols, data were prepared for analysis. Analysis of data was done for ten of the participants; eight collections received minimal processing consisting of time indexing and notation of actions. It was originally intended to use all the data sets, but as analyses proceeded, it became evident that the ten already analyzed would be sufficient. Thus, the eight that were not subjected to full analyses are available for follow up use.

Data Preparation

The video tapes held two different types of data--verbal reports and actions. Video tape is unexcelled as a medium for faithful reproduction of the movements and behaviors of a session. But, in support of a more accessible use of the verbal reports and the actions, both protocols were reduced to written form.

Preparation of the Verbal Report Transcription

The verbal record was transcribed by a professional transcription company. No special instructions were given, thus the transcribers used common signals of pauses and silences to break the verbal report into sentences and phrases. Lengthy silences were indicated with ellipses; inability to understand a word or phrase were also indicated. Indications of affective gestures such as a laugh or giggle were sometimes recorded. Transcripts were presented with line numbering, double spaced, and with the text broken into paragraphs. No other formatting was done by the transcribers.

The written transcription was then indexed by the researcher to indicate time by minute. This segmentation was done manually by watching the tape, drawing a line through the transcription record after each minute of duration, and noting the time at the beginning of the line. The purpose of this indexing was to facilitate identifying locations of events or incidents of interest in the record.

Preparation of the Action Report Transcription

Actions were added manually to the written transcription by the researcher. Actions were identified informally. Those actions that were noted consisted of such behaviors as picking up a new document, or writing a note. They were annotated in the margins of the transcription.

Analysis by Constant Comparison

Analysis was done in repeated passes through the data. Since the intent was to *discover* categories, structure and relationships, it was impractical to use predetermined coding schemes. An analysis technique was required that supported constant redesign and reintegration of the developing categories.

Analyses used the constant comparison method of inductive data reduction. This method inspects data for properties and records properties that are discovered. It is an explicit effort to develop systematically the categories and their interrelationships available in the data.

The procedure of constant comparison is straight forward but time-consuming. First, identify and select one example of the phenomenon of interest. Examine this incident. Identify as many categories as possible in this incident. The first incident may suggest either broad groupings of actions or very detailed specific behaviors. Next, take a second example of the phenomenon and apply the defining rule of the method: while examining an incident, compare it with previous incidents of the same type, noting differences and similarities of properties or conditions that occur. As subsequent incidents are considered, group the incidents, changing earlier groups, adding new groups, or combining previous groups. Develop tentative criteria for inclusion of incidents in each group. Continue in this manner with each incident until all have been accommodated in the developing schema. The schema has been developed incrementally, reflecting the occurrences of properties in the totality of incidents. The criteria for inclusion in a group gradually become stable, and groups are able to accept new incidents without change. As Glaser and Strauss (1967) point out, " . . . as the coding continues, the constant comparative units change from comparison of incident with incident to comparison of incident with properties of the category that resulted from initial comparisons of incidents" (p. 108). The properties of the category begin to integrate, that is, become related in many different ways. Comparison has gradually become encoding, using the developing categories.

Although the procedure implies a single pass through the data during which all relevant formation of categories and relationships is accomplished, use and understanding of the data in this study was built over a sequence of passes. Each pass concentrated on a slightly different objective. One review looked at the entire session with the aim of identifying structures and types of information that comprised the context of problem solving by the participant for the assigned problem. Another review looked at individual interactions with information with the goal of discovering the types of transformations that occurred during problem solving. In problem solving terms one review was attempting to specify the state, whereas the other review was concentrating on the operators. The information developed from all passes is integrated in the final result.

One review of the data sectioned the session into three major parts: start up, use of information sources, and writing. Each of the sections were then treated as individual incidents for comparison. Attention was directed to the contributions of the participant, although the actions of the researcher and the materials provided were considered also.

Start Up

The start up section was defined as that portion of the session from the beginning of the tape through the first request to "State in your own words the information need as you understand it at this time." This division point was chosen because it is easy to identify and because it marks the end of most of the interaction between the researcher and participant. From this point, although occasional interactions occur, the participant concentrates on the use of the materials and the development of the requested product. Start ups were examined for evidence of structures and constraints that were initially produced by problem solvers.

Use of Information Sources

Use of information sources was identified as the second part of the session. This portion included all of the session that involved selecting, reading and using the information sources provided by the researcher. Although this is a natural sounding break, the boundary on the terminating end of the phase is not as clean cut as that for the first part.

A number of participants used sources as reference during the writing stage, and some participants began writing as they used the sources for the first time. In these circumstances, the inclusion of a portion of the session in either the second or third part was decided by the researcher based on the preponderance of activity. If the participant is just beginning the task, and begins to prepare the response, then the incident is classed in part two. If the participant has been using the information sources, begins to prepare the response, and refers to the sources for quotes or as a memory aid, the incident is classed in part three.

IWI Definition

The data stream of the portion of the transcript concerned with use of information sources was parsed into individual incidents of interacting with information, abbreviated IWI. The concept of IWI was developed to meet the two characteristics of a "unit" that Lincoln and Guba recommend: one, to be heuristic, and two, to be the smallest independent piece. (Lincoln and Guba, 1985, p. 345) To be heuristic meant "aimed at some understanding or some action that the inquirer needs to have or to take" (p. 345). To be independent meant "it must be interpretable in the absence of any additional information other than a broad understanding of the context in which the inquiry is carried out" (p. 345).

These interactions occur throughout a session. A decision was made to concentrate on those resulting from the use of the seven written information sources. This choice reflected the study's concern with the use of public information sources in problem solving. However, examination of all parts of the transcript was based on a *de facto* IWI -- the presentation of information followed by the problem solver's verbalized or observed response to it.

For each set of protocols that was used, a selected set of IWI incidents was examined consisting of those resulting from the use of the first source, one intermediate source and the last information source. The choice of intermediate source was made so that each position (i. e., second, third, etc.) was represented across all participants. Thus for a single participant, IWI instances for the first, an intermediate, and the last source used were identified and compared.

Interacting with information (IWI) was defined as a stimulus of information followed by a response from the participant. This combination is readily identifiable in the stream of data, mainly because of the existence of a response. The conclusion of an IWI incident was signaled by the beginning of articulation of different text (reading) or a long pause (quiet period) in the participant's report following a response. Intake of different information started a new IWI instance.

The information portion of an IWI incident was identified manually through a comparison of the report and the written text. An information stimulus was not always fully articulated. Reading part of the information source's text was sometimes silent. In these cases, the stimulus was known to have occurred by observation of a reading action on the video tape and by the presence of a response. Silent reading is quite common in all the protocols. Even though much reading is reported, not all of it is. Many examples are found of quiet periods followed by the reading of information that occurs later in the source.

From the verbal report it is not possible to decide if the participant read all the intervening material. Sometimes it is possible to see on the tape that the participant is reading, but still one does not know exactly what is being read. For purposes of identifying IWI instances, the annotated transcript was used and questions were resolved by viewing the tape.

Here are some IWI examples, with explanations of characteristics that occurred. (The information is in plain text; the participant's words are shown in italics. The reference at the end is an identification code used by the researcher as a locator for a quoted passage in the data transcripts.)

Example 1.

> "Automatic selection of terms. *Okay. They're talking about stop lists which eliminate function words. Okay I remember that from 670. Stop list words. And then they have--they call them go list words, I never heard that, but that's clear, and those are descriptors, okay. Okay.*" (b2.1704.5)

This would be considered one IWI incident. In the information source, the stimulus occurs as a subheading in the text and is read and repeated in the think aloud protocol exactly as it occurs: "Automatic selection of terms." The terms "stop list" and "go list" occur in the paragraph following this subheading. Their occurrence in the think aloud report indicate that the participant did access them, but did not report them as part of reading. The articulated stimulus is used as the beginning of the IWI incident and also includes the unreported parts of the information source.

Example 2.

> "(Inaudible mumbling) fiction writer is really all of these. The teacher and artist most of all. First think of the nonfiction

> writer as a teacher, after this an artist. *Okay. Artist. That's artist writer, artist illustrator.* (c18.1905.11)

This is also one IWI incident. The actual words in the information source were "Teacher. Scholar. Promoter. Artist. Reporter. Catalyst. Philosopher. A fine nonfiction writer is really all of these. But teacher and artist, most of all. First think of the nonfiction writer as teacher. After this, as artist." The report differs in minor details from the actual source. For example, the report shows articles in several places where none were found in the source. Reports of protracted reading, such as several sentences, are very rarely exact matches with the source. Changes from the text include both omissions and insertions. More severe mismatches than inclusion of articles are found. For this study, mismatches and rewordings are usually ignored as irrelevant if the words are identifiable as those of the author. That is, changes of syntax and word order are not considered to be responses to an information stimulus. On the other hand, the juxtapositions of artist with writer and artist with illustrator are not information stimuli, since these phrases do not occur in the text, but represent the participant's contribution based on the information just taken in.

Reworking of the text, as opposed to rewording of it, however, is considered to be a response rather than a stimulus. Although many of the same words occur, reworking includes more input from the participant and is therefore more response than stimulus. Here is an example of reworking information that was read.

Example 3.

> "Publisher's perspective. *This one is talking about juvenile nonfiction books, the shift and* how they're conceived, written and published for -- *this thing is right on target.*" (c17.1419.7)

The text was entitled "A Publisher's Perspective" and the first sentence was "Over the past decade there has been a dramatic shift in the way juvenile nonfiction books are conceived, written and published." In spite of using the text, this report indicates more than just taking in the author's words. It reorganizes the content of the sentence. It appears to be telling about what was found rather than finding it.

Writing

Writing was defined as that part of the session in which the participant prepared the written response that had been requested as part of the task. This phase does not include the note-taking that was done by a number of participants. Note-taking was considered as an activity related to using the information sources. The use of the notes occurred in both parts.

Conclusion

This chapter has described the data collection and analyses that were done in the study. The study depends upon the paradigm of qualitative exploration for its coherence. It intertwines the contribution of rich data via collection of verbal and action protocols with the inductive method of incident comparison to discover the structures and operators of the phenomenon of constructing personal knowledge. By adhering to the guidelines for collection of verbal reports, reliable data concerning the phenomenon of interest were collected and were available for analysis. By following procedures for systematic production of categories, underlying similarities of purpose and function were able to be identified and named. Chapter Four presents the results.

CHAPTER 4. A FRAMEWORK FOR INTERACTING WITH INFORMATION

The results of the data analyses are to be presented in the form of a frame model. The model shows the structural elements and the operators that have been found in the data. It also depicts the interactions that occur between the operators and the structural components.

FRAMES

A frame is considered a variety of a more general class of structures known as schema, which includes frames, scripts, stereotypes or rule models. These distinctions are based on differences in the focus of attention: frames are used to describe common attributes of objects; scripts, a sequence of typical actions for a particular activity; stereotypes, clusters of characteristics of people; and, rule models, shared features of a set of production rules. (Rich, 1983, pp. 203-204) The salient feature shared by these types of schemata is the co-occurrence of features or attributes and at least one implied relation among those attributes. The frame version is chosen as the form for describing concepts and mental representations.

A frame is generally regarded as "a data structure composed of a series of SLOTS that hold values, characterized by its versatility" (Thro, 1991, emphasis in original). Slots are filled with values derived from the particular instance being represented, or with a default value derived from the most common value for an attribute. Slots may also be filled with another attribute, creating a taxonomy of attributes. (Tanimoto, 1987) A frame provides a representation of objects or concepts by depicting a set of attributes and values. In addition to the attribute-value sets, the concept of frame implicitly includes a relationship between the attributes. The basic fact of grouping attributes indicates a perception of some relationship between them. Tanimoto (1987) conveys this by saying, "A frame is a *collection* of knowledge *relevant* to a particular object, situation, or concept" (p. 112, emphasis added). In many cases, the relation is the simple one of "part"; attributes are each some "part" of the overall concept of which they are members.

The frame concept used in this research is based on the exposition in Barsalou (1992). Barsalou identifies the basic components of a frame as attribute-value sets and two variations of relations, structural invariants and constraints. An attribute is an aspect of members of a category, although not all members may exhibit the attribute. A value is a subordinate concept of an attribute and depicts an actual kind or type of concept that the attribute may assume. Relations that hold generally across most exemplars of a concept are termed structural invariants; those that produce systematic variability in attribute values are constraints. A common structural invariant that integrates components of a frame is that of part and value, labeled as aspect and type by Barsalou. Constraints derive from statistical patterns, personal preference, and cultural norms and may occur between attributes, between values and between aspects of a frame or a structure of frames. (pp. 28-40)

In addition to the basic concept of frame as representing "timeless states of the world" (p. 54), Barsalou expands the use of frames to depict processes as "dynamic flow of events over time" (p. 54), as, for example, an event sequence. He depicts a process by showing that some aspects of a concept may take different values based on the state of another aspect. In brief, an event sequence is represented by crossing aspects of the model and noting intersections. A grid is used to display the intersections of these interacting aspects. This use is more easily grasped if seen graphically, as will be shown later in the chapter.

Showing the interaction of parts of a concept is particularly appropriate for the presentation of interacting with information. It lends itself to the effective presentation of the states and operators that comprise the problem solving components identified in this study. Using a grid to display intersections of interactions and involved structural components is an efficient technique for showing both. The next section develops the model structure and gives examples of using the model to understand IWI.

Frame Model for Interacting with Information

A model requires that its structural components be identified and described and that the model be shown in action.

Displaying the results of an analysis does not have to follow the same sequence as the development of an analysis. For clarity of presentation, the model is described in a top down fashion even though it was developed from the bottom up. It seems to be easier to understand the model when a higher level of grouping is discussed before going into its details. The entire model is shown in Figure 4.1 and in indented outline form in Appendix A.

The model shows the structures which actualize the state of the problem solver. Structures represent the kind of knowledge considered to be part of an individual's knowledge base. Each subordinate level is an aspect of the preceding level to which it is attached. Terminating aspects, shown as the final levels in the figures, have types as their subunits. Types are not shown in the chart but are presented separately in *italics* in the text. For convenience in identifying a structure, each is numbered. The number gives the levels of the branches and aspects and is therefore called a Branch and Aspect (BAS) level number. It appears in parentheses following the structure when it will assist in locating or tracking a structure. In the text, structures are shown in UPPER CASE for convenience in separating them from other phrases using the same words. The relation "part" is the connection between all structures.

Components of the Frame Model

Interacting with information is considered the key and encompassing action in information problem solving. The frame model begins with the structure INTERACTING WITH INFORMATION (0) as the top level. Figure 4.1 shows the model. As an aid in following the description of the model's components, each branch is depicted again in its own figure at an appropriate place in the chapter.

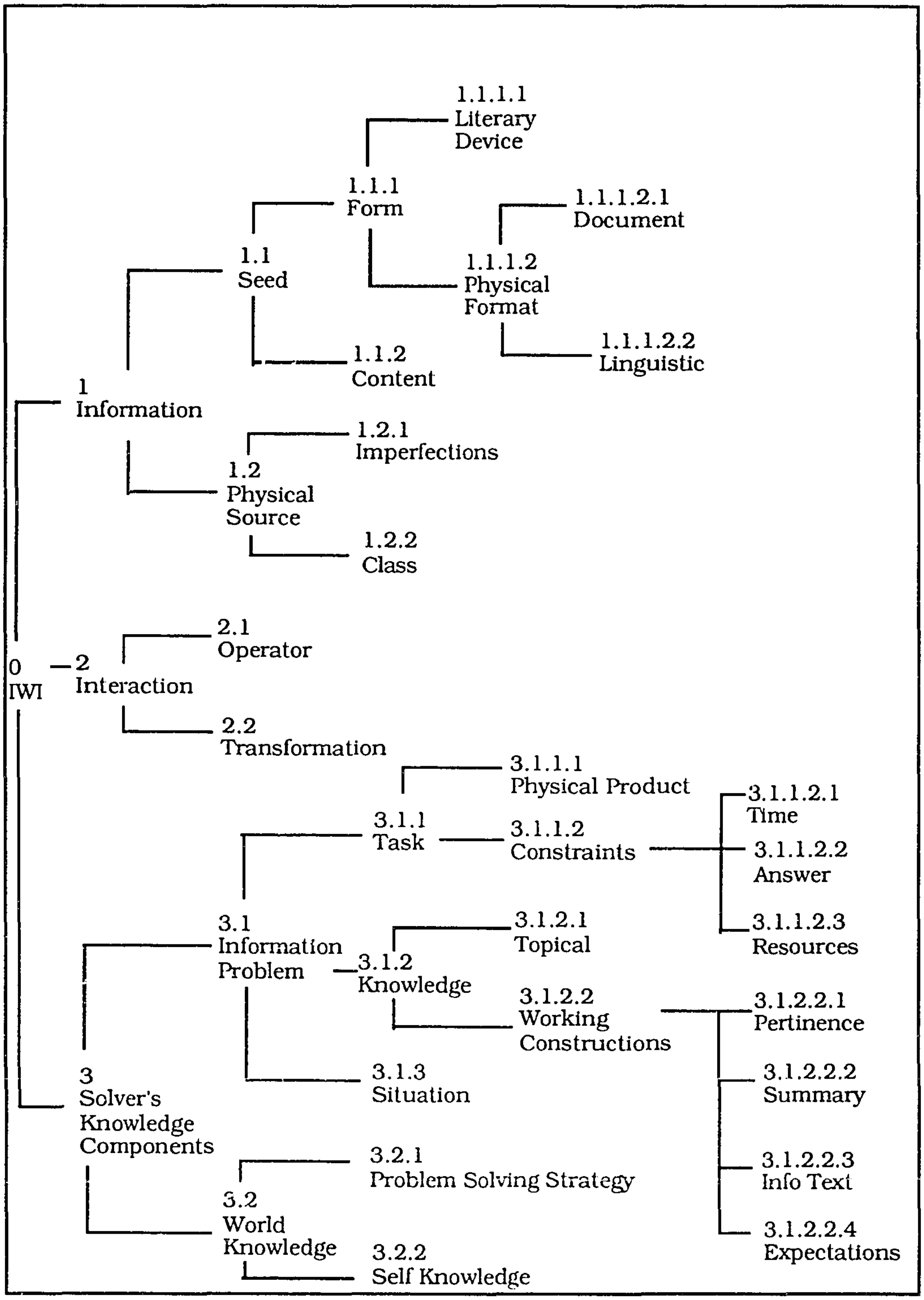

Figure 4.1. Frame model INTERACTING WITH INFORMATION

The figure shows the three major branches of the model. These three branches represent the major elements of interacting with information. An IWI incident is composed of an INTERACTION which depends on incoming INFORMATION and SOLVER'S KNOWLEDGE COMPONENTS. Together, these three aspects present a high level view of interacting with information (IWI).

INFORMATION (1) is that branch which collects problem solver recognized aspects of the public information available for use in problem solving. It is the structure used to depict the problem solver's view of the information sources and represents both the external aspects as recognized, and the mental representation of those aspects held.

The SOLVER'S KNOWLEDGE COMPONENTS (3) is the branch which represents the internal state of mind of the problem solver. Its aspects concern both previous knowledge held by the problem solver and the new or changed knowledge that the problem solver constructs during problem solving. It is not the contents of the structure which are specified; rather, it is the kind of knowledge structures involved in information problem solving.

An INTERACTION (2) is that branch which represents the operations evident in problem solving. It presents the kind of behaviors and the resulting kind of transformation that use and affect INFORMATION types and SOLVER'S KNOWLEDGE COMPONENTS structures.

Frame Branch INFORMATION (1)

The INFORMATION (1) branch is depicted in Figure 4.2. INFORMATION represents the outside or public information sources that were available to the problem solver. There were two aspects recognized by the problem solver. A major role is that of stimulus, which is recognized in the SEED (1.1) structure. Separate from the role of stimulus is that of INFORMATION as a physical artifact, shown as the structure PHYSICAL SOURCE (1.2).

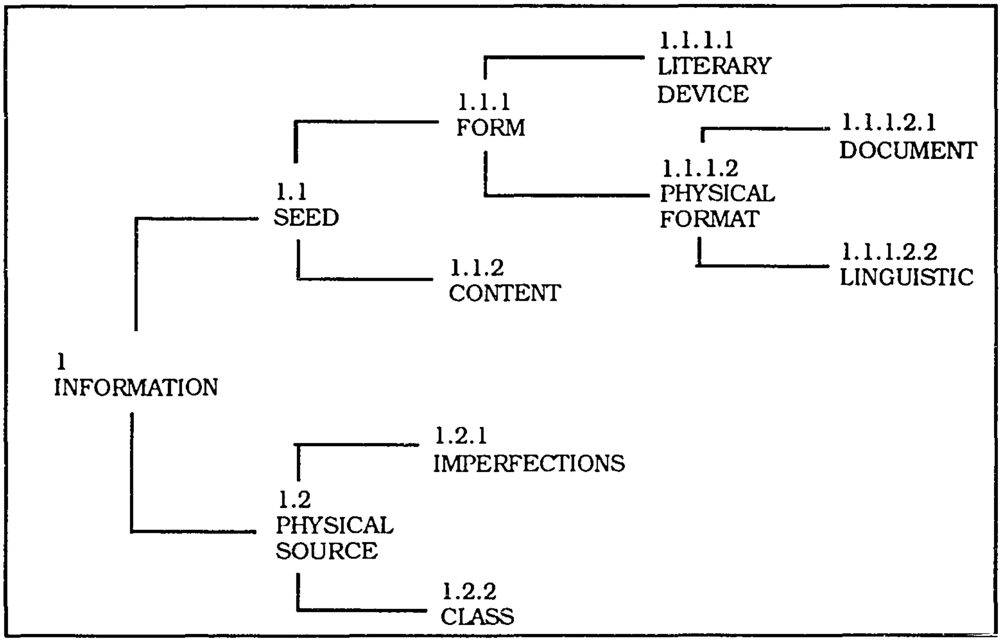

Figure 4.2. Frame Branch INFORMATION

SEED (1.1)

SEED (1.1) represents a function of information that is most clearly described as that of an actuator. It instigates action by its initial presentation of new information, which forms the seed for the growth of knowledge by the problem solver.

In examining an IWI instance, one distinguishes the words of the document from those of the problem solver by examining the document in conjunction with the report of the problem solver. In many cases, however, in order to determine the *type* of information actuator, it is necessary to rely upon an inference drawn from the problem solver's own words. Knowledge of linguistic features such as anaphoric reference plays a large role in making reasonable inferences. Fillmore (1985) calls this kind of text interpretation linguistic analysis and describes it briefly:

> We attribute to the interpreter of an ongoing text an awareness of at least certain properties of what is currently "in the buffer," a memory of what complex state the interpreter was in just previously, the knowledge of repertories of items and structures (at many levels, and simultaneously), the knowledge of a set of principles characterizing the language in question, and the ability to generate expectations from this complex of awarenesses and knowledge. (p. 17)

It is this type of analysis, usually performed tacitly, that supports the inferences that are made. Still, more than one inference based on the information and the words of the problem solver may be reasonable.

SEED has two aspects of interest: the FORM (1.1.1) of the stimulus, and its CONTENT (1.1.2) features.

FORM (1.1.1)

One aspect of SEED is rather complex. FORM (1.1.1) is the aspect which classifies information within IWI incidents in terms of rhetorical features; that is, the information is identified as either a LITERARY DEVICE (1.1.1.1) or a PHYSICAL FORMAT (1.1.1.2). The intent is to capture the types of literary expressions that were the initiator of an interaction, although one must be careful not to impute cause to the juxtaposition of text and response.

LITERARY DEVICE (1.1.1.1) LITERARY DEVICE (1.1.1.1) contains those types of information which are recognizably literary modes of expression, such as *Metaphor* and *Analogy*, and includes literary contrivances such as *Example, Quotation, Acronym, Rhetorical question* and *Personal name*. An example of each of these types is shown below. The literary device is either identified by the problem solver in the verbal report, i.e., *Metaphor*, or it is identified by using a common definition of the type term, i.e., *Analogy, Acronym.*

Both *Metaphor* and *Analogy* indicate recognition of the respective literary device and their ability to engender an interaction. The use of an *Example* or *Personal name* may elicit a recollection of a personal experience. A *Quotation* presented by an author sometimes will bring a response of approbation; whereas the response to a *Rhetorical question* is to answer it. *Acronym* may cause problems with understanding and sometimes this confusion is reported by a problem solver. (The written text in the document is shown here in plain text; the problem solver's own words are in italics; actions are annotated within square brackets.)

> <u>Metaphor:</u>
> "[Reads a document] Gifted writers work with facts as sculptors work with clay. *That's an interesting metaphor.*" (c18.1909.13)
>
> <u>Analogy:</u>
> "[Reads a document] She uses this term, Pied Piper, to describe certain outspoken scientists. These scientists captured the imagination of the public. *I wonder why she used Pied Piper? Because of the rats, I guess. Leading people. Okay.*" (c18. 1911.8)
>
> <u>Example:</u>
> "[Reads a document] Focus is also important in natural history titles-- *is another book they're talking about. Why it's good. And here's Lauper's book again. The same damn book on volcanoes. I wonder why they chose that one, because she wrote a whole bunch of different books that are all very similar to each other. The volcano one is nice, but so is the one on icebergs.*" (c17.1422.3)

"[Reads a document] 1978 the award went to Judith and Herbert Cole for a View from the Oak. *I haven't read this.*" (c18.1920.4)

Quotation (a quote presented by the author in the text): "[Reads a document] . . .read, and reread, looked at, skipped, pondered over, completely at the disposal of the user. They do not cut one's finger [inaudible] nor stick one's cuff with paste. They do not form gritty patches on the floor like sand, not wet messes like water. The world's books contain the world's knowledge. Surely [inaudible] to help children how to use them. *Oh, that's good.*" (b16.1251.8)

"[Reads a document; writes a note; pause] *Okay. The next quotation is this is* [sic] *all about narrative?*" (c18.1914.21)

Acronym:
"[Reads a document] *G-U-I. What are GUIs?* Graphical user interfacers. *Hum. Okay.*" (b2.1715.11)

Rhetorical Question: (Author's question in text elicits response)
"[Reads a document] And finally, he comes back -- I come back to where I started, the possibilities of nonfiction writing for young readers. Does it have nothing but facts? Is there a function? Is there room for ideas, for exercise of judgment? For a portrayal of character? *Yes.* For the elimination of human behavior? *Yes.* A display of craftsmanship? *Yes.*" (b16.1242.6)

Personal name:
"[Reads a document; pause] *Well, it's nice to see that the author of our textbook in 681 is mentioned.* Zena Sutherland." (b16. 1225.20)

PHYSICAL FORMAT(1.1.1.2). PHYSICAL FORMAT (1.1.1.2) acknowledges the role of physical devices as initiator for an interaction. This aspect is composed of two further aspects, DOCUMENT (1.1.1.2.1) and LINGUISTIC (1.1.1.2.2).

DOCUMENT (1.1.1.2.1). DOCUMENT (1.1.1.2.1) encompasses parts of the information source that were seen to elicit interactions and includes the following types: *Publisher, Publication date, Title, Subheading, Table or* *chart, Footnote, Abstract,* and *Author.* These types are reasonably easy to recognize in an IWI incident. Frequently, the problem solver's words indicate the feature, i.e., *Publication date* or *Footnote,* or the juxtaposition of the problem solver's comment with the text feature clearly indicates the feature, i.e., *Table or chart* or *Abstract.*

As can be seen from the types of this aspect, several pieces of bibliographic information may be the basis of an interaction. *Publisher, Publication date, Title* and *Author* were all put to use at one time or another by a problem solver. Several formatting features of documents, *Subheadings, Abstracts* and *Footnote,* were also found as initiators of an interaction. And, the existence and compactness of a graphical aid in the article was noted by at least one problem solver. Examples for clarification are provided here.

> *Publisher:*
> "[Reads a document] This piece of expertise could be incorporated within an expert system. Meaning also applied probability techniques. *I don't know, from this article I know I wouldn't be too thrilled about automated indexing. It's almost from the indexer. I wonder if that's the British -- oh, yeah, text and address given in London. Okay, that's why it had that."* (b2.1707.20)
>
> *Publication date:*
> "[Reads a document] Text indexing program. *Um. Well, when was this written? 1990, so."* (a4.1528.19)
>
> "[Looks at set; reads titles] What's Ahead for Indexing Software. Getting Started in Computerized Indexing. Indexmaker [inaudible] *Well, that's earlier so that's probably not up-to-date as these are. This one is older, too."* (b3.1525.20)
>
> *Title:*
> "[Reads a document; title is "Trends and Evaluative Criteria of Informational Books for Children"] Trends and evaluative criteria. *Okay.* This one says, trends and evaluative criteria of informational books for children. *So it sounds like it would*

talk about development. Or the change, at least, in the ways that they're doing things. Okay." (b19.1535.19)

Subheading:
"[Reads a document; some of the subheadings in document were Humor, Unusual Formats, Simplification of Advanced Topics, Evidence of Research] These things [inaudible] here. Because humor, unusual formats, simplification of advanced topics [inaudible] evidence of research focus. *This is what? So the* trends *are into these areas.*" (c18.2009.5)

Table or chart:
"[Silent reading; viewing of table of comparisons in the document evident from visible action of examining the table in conjunction with the problem solver's words in the report] *Interesting comparison of same index in different packages. So,* [inaudible] *right now.*" (b3.1517.23)

Footnote:
"[Reads a document] Computer assistance, *the next section of this article,* provides word processing. *How does that apply? Keep referring to other authors with footnotes, that's really distracting. Okay.* [Pause in report] *Still hasn't really said what computer assistance* [inaudible]." (b2.1652.18)

Abstract:
"[Reads a document; boxed abstract follows title and author] Software tools for indexing, what we need. *Maybe this summary -- if this is a summary, maybe it will help me decide if it's any use.*" (c8.1051.15)

Author:
"[Sets aside a document; picks up a new document; reads title] *This one is called Filling Vases While* [inaudible] *but since it is also by Jo Carr, the author of Literature of Fact, I'll put this down to see what Milton Meltzer has to say about the* possibility that [sic] nonfiction writer's view. *I like Milton Meltzer, I've read many articles by him so this should be an interesting article.*" (b16.1236.12)

LINGUISTIC (1.1.1.2.2). LINGUISTIC (1.1.1.2.2), the second of the aspects of PHYSICAL FORMAT, contains types which are readily identifiable as a linguistic unit, such as word or sentence. The structure

LINGUISTIC contains linguistic types that are basic designations that could be made about any of the written information. Written information owes its existence to being recorded in a linguistic form, such as a word or sentence. An IWI instance may contain a LITERARY DEVICE (1.1.1.1) and at the same time be expressed in some type of LINGUISTIC type. When examining an IWI instance, the most informative of the FORM aspects naturally claims the most attention and is given precedence in deliberations about the IWI instance. Less informative aspects remain available for consideration if appropriate.

The value of recognizing LINGUISTIC as an aspect is that it highlights the variation in proportions or extent of information that are used by a problem solver. What is intended is to convey the idea that problem solvers grapple with units of information that vary in range from a concept expressed in one word to an integrated product of several facets of information. LINGUISTIC types include *Word, Phrase, Sentence, Paragraph,* and *Non-contiguous sentences.* A *Word* is defined as a set of letters surrounded by white spaces and includes compound words, such as operating system, which are understood as one word. *Phrase* is used to recognize less than a full sentence, whereas *Sentence* is used for both a single and multiple sentences, as long as the sentences are adjacent and do not comprise an entire paragraph. *Paragraph* recognizes the use of an entire paragraph as written by the author; *Non-contiguous sentences* recognizes more than one sentence when they are not adjacent to each other. Examples of each type are illustrated below.

<u>*Word:*</u>
"[Silent reading] Drama. *I believe that drama has to enter into style.* [Silent reading] *If -- and this is true, that drama*

features a person and a person that we can identify with then *we want to keep reading.*" (b16.1228.3)

"[Writes note on separate sheet of paper] Oh, eloquent style. *There's the word. Not poetic. Eloquent.* Eloquent style and graphic description." (c18.1917.22)

Phrase:
"[Reads a document] Once a file of unsorted index entries have been accumulated -- *oh, so you just keep entering them randomly, then you hit a key,* check entries for style, then it detects errors in the entries indicating line number and error *something -- oh, error types, I guess.*" (b2.1751.20)

Sentence:
"[Reads a document] And subentries -- subentries are usually sorted in the same order as main entries, however, prepositions, articles and conjunctions are ignored. *Okay.* [Writes a note]" (b3.1514.12)

Paragraph:
"[Reads a document] During the operation, the package displays the text being indexed. While index processing is going on the package informs the user of its progress by displaying a percent bar chart at the bottom of the screen. During the operation of the package displays the text being indexed. *Oh, that's good. Text display -- text displayed during indexing.* [Writes a note]" (a5.1202.11)

Non-contiguous sentences:
"[Reads a document] Should clarify and extend the text. Explain labels and captions. Children can learn as much from illustrations as from text. They can -- they cannot merely be colorful and -- not be merely colorful insertions, but can actually relate fact. *Here's a story of the Statue of Liberty mentioned again.* [Refers to example (Statue of Liberty) in next paragraph from the one being reported on] (c17.1500.20)

"[Reads a document] Mass market word processing software offers computer users the ability to [inaudible] and leading -- um -- these have a missing link in the chain of tools available for document production. That missing link is availability -- is the ability to prove -- prove the indexing conforms to even the most basic indexing standards in American publishing. *What are they?*" ['Missing link' occurs in a following paragraph from that with information on mass marketing] (c8.1052.9)

CONTENT (1.1.2)

CONTENT (1.1.2) is a difficult aspect to describe. It is intended to represent the event in which the actual topical content of an IWI instance seems to give rise to an operation. This seems obvious and may even appear to be the main if not the only stimulus that would create an interaction. It is not, however, the only one, although its frequency of occurrence has not yet been determined. The intent of this aspect is to focus awareness upon those instances when the problem solver is relying upon topical content rather than other INFORMATION aspects. It contrasts with instances when the FORM of the information expression appears to elicit an interaction.

Content, of course, comes in infinite topical variety. No attempt was made to develop a taxonomy of content in terms of topics; rather, the types chosen try to depict the role that content played as stimulus. Two types were found: one, an *Individual topic* contained in the IWI report and the second, the portion of the document read to date, labeled *To-date.*

An *Individual topic* is the type used when a single facet of information in the information source seemed to be the initiator of some operation. It may seem that *Individual topic* and *Sentence* are too similar to distinguish, given that most sentences express a complete thought about a single subject. They are distinguished by use. That is, when the individual topic is more specifically definable in the interaction, it is used; when it is unclear as to what the problem solver is responding to, *Sentence* is used as the less specific classification.

In the following example the initiator of the interaction is a single facet of information found in the text of the document; it is labeled an *Individual topic.*

> Individual topic:
> "[Reads a document] The user manual label changes to the merge file is [sic] dangerous. They're definitely not recommended. *Wonder if that means creating two files and then merging them or just merging new entries in with the old one?*" (b1.1330.19)

Sometimes, the item that elicits an interaction is more than one topic or one piece of information in the text. To distinguish these, the type *To-date* is used. This type implies that the information being operated on is more than a single topic, and is probably all that has been taken in to date. *To-date* differs from *Summary* ((3.1.2.2.2), to be discussed under SOLVER'S KNOWLEDGE COMPONENTS) by referring to the information that is the basis for the action rather than the product of that operation. *To-date* attempts to indicate that an operator is using more than a single topic in the ongoing operation.

The following two examples show the problem solver summing up in an abstract way what has been read to date:

> To-date:
> "[Reads a document] This means that if major changes and practices are made during the process of indexing a work, reflecting those changes in the index can be extremely inconvenient. Index-It does not support multiple levels of indexing. *Well, it tells us what it can't do, let's see what it can do.*" (b1.1330. 24)
>
> "[Reads a document] [inaudible] PC based word processing product claims unavailable -- indexing standards. *What else is this talking about?*" (c8.1053.16)

PHYSICAL SOURCE (1.2)

The second aspect within INFORMATION is PHYSICAL SOURCE (1.2), which represents the physical manifestation of the information source. Information for problem solving is available from more than one kind of source, represented by CLASS (1.2.2), and has some physical characteristics, represented in IMPERFECTION (1.2.1), which may elicit interaction from the problem solver.

IMPERFECTIONS (1.2.1)

IMPERFECTION (1.2.1) is the aspect of PHYSICAL SOURCE that collects the physical problems of the information source that are noted by the problem solver. At times, an imperfection in the physical document initiated an interaction; for example, truncation of words in the source documents was produced unintentionally during the reproduction of the documents. One type was found for this aspect : *Truncated word*. Identification of an incident was usually marked by an overt remark by the problem solver.

> *Truncated word*:
> "[Reading a line in which one letter is missing from the left side of the words] *Oh, did I miss something?* 37 page *something* instructions, very useful in the [*inaudible*] suggestions. Package poses no intellectual *what?*" (a5.1223.13)
>
> "[Read a document] Begin with numerals, be forced to sort in desired order by -- *I just can't figure this out because these words are cut off.* [inaudible] *is that on the next page?* Forced to sort in desired order by *something* non-printing text before the first [inaudible]. *I cannot read it. This one must be part of the test. Oh yeah, no bugs is a good thing not to have. But this one was really hard to read because of the words cut off.*" (b3.1530.19)

In the first example above, the second "something" (after page) substitutes for the truncated word "-anual," which in context is the word "manual." The inaudible portion also covered a truncated word, as did the "what" at the end. This problem solver chose a strategy of substituting place holders (i.e., "what") for the truncated word. In the second example, created by the same truncation, a comment and extra reading effort were elicited by the problem solver's inability to repair the damage.

CLASS (1.2.2)

CLASS (1.2.2) is the aspect of PHYSICAL SOURCE which identifies the type of information source involved in an interaction. It consists of *Information source document, Problem statement, Set of documents,* and *Oral* (discussion with researcher). These types are intended to identify information by its physical representation.

Information source document is the type which provided the majority of information about the topic to problem solvers. It represents an individual document. If it is necessary to know that a particular document is involved in order to present the activities of the problem solver clearly, this type may be expanded into its seven separate instances, each being referred to by its color (each document was presented on different colored paper to support identification during analysis). This structure, then, may exist independently for each document.

Examples are shown below.

> *Information source document:*
> "[Sets aside document in use; chooses another] *Okay. Let's look at Grosh, Index-Aid.*" (b3.1528.11)

> "[Sets aside document in use; chooses another] *Okay.* What's Ahead for indexing software. *Let's try this one, maybe this one is more readable.*" (b2.1707.5)

The main vehicles for delivery of task information were *Problem statement* and *Oral.* A written *problem statement* was available throughout the session and was consulted as desired by a problem solver.

> Problem Statement:
> "[Picks up problem statement] *So this might be software -- using the materials provided -- um, I'm going to cross out using the materials provided, okay, want half a page about important capabilities for a software which is used to create back of the book indexing. Okay. What I have just finished, crossed out words that are insignificant, I want half a page and I want important capabilities for software used -- crossed out which is, underline used to create back of the book index. I'm going to stick with only back-of-the-book indexing.*" (a5.1210.3)

Oral instructions were delivered at the beginning of the session and in response to questions from the problem solver during the session.

> Oral:
> "Subject: *So you want me to really go through the whole thing and have a half a page or so written?*
> Researcher: What I want you to do is do whatever you would normally do if someone asked you to write a half a page or so about this topic." (c17.1355.8)

Set of documents refers to the information sources as a group. It includes the concept of items being physically together. *Set of documents* may also be fragmented into subsets. If it is necessary to refer to subsets for clarity, they will be identified by listing their members, and labeled Set.*n* for future reference. A Set.n may consist of a single document; if a set contains all the documents, it becomes *Set of documents.*

<u>Set of documents</u>:
"[Picks up set of documents] *Okay. Nonfiction. Let's see, we have one, two, three, four, five, six, seven articles here. They look pretty lengthy. I don't think I can read through all of them right now, so what I'm going to do is skim them and see if I see reference to what looks like the subject and maybe I can clarify what literary art is talking about.*" (c17.1359.4)

"[Looks at document set] Index-it, Low Cost Indexing Software by Steven Harter, Index-Aid, *these are separate programs.* [inaudible] software review. Macrex. *Oh, it's a review of Macrex.*" (b3.1525.15)

"[Sets aside document in use, picks up two documents] Getting started. [Partial title of one document] *I'll pick this over* Software Tools for Indexing [Title of other document]. *Because I'm not sure what they're talking about as far as tools. Curiosity should make me read that. Maybe I'll start with the first sentence.* [Reads from first document] There is no doubt that software and hardware tools for document processing on personal computers advanced tremendously. Software tools for indexing. *So all it's saying is that its going to use a computer to help do indexing.* [Reads from second document] Getting started in computerized indexing. The functions of an index, automation indexing is concerned with mechanizing clerical routines attempting to reproduce complex, intellectual operations. . . ." (a5.1226.17)

<u>Frame Branch SOLVER'S KNOWLEDGE COMPONENTS (3)</u>

The SOLVER'S KNOWLEDGE COMPONENTS (3) is presented in Figure 4.3. SOLVER'S KNOWLEDGE COMPONENTS emphasizes concern with the components of the states of the solver's knowledge.

SOLVER'S KNOWLEDGE COMPONENTS is composed of two aspects: knowledge about the INFORMATION PROBLEM (3.1) and general WORLD KNOWLEDGE (3.2) which is brought to the session by the problem solver. These aspects parse the knowledge of the problem solver

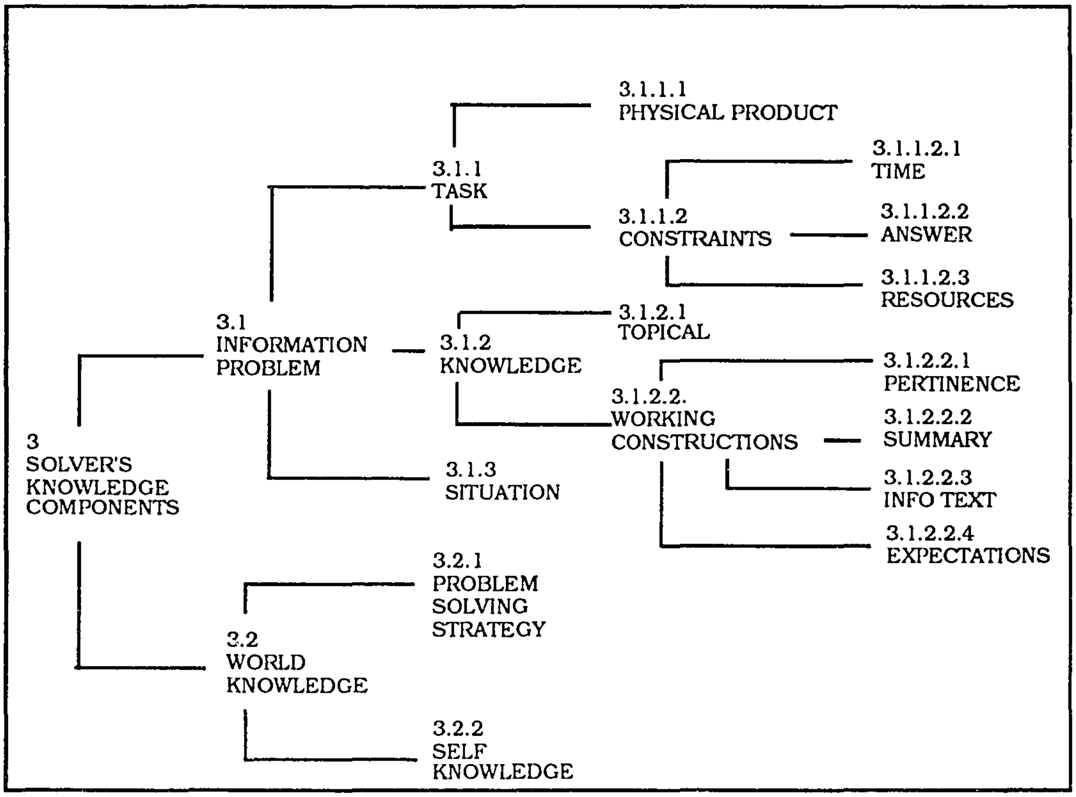

Figure 4.3. Frame Branch SOLVER'S KNOWLEDGE COMPONENTS

into the modules reflecting the structure of the solver's personal knowledge important to this undertaking and particularize the kinds of knowledge salient during information problem solving. SOLVER'S KNOWLEDGE COMPONENTS is the repository of the developing knowledge about the solution to the problem, as well as the store of knowledge that the problem solver brings to the session.

SOLVER'S KNOWLEDGE COMPONENTS (3) differs somewhat from that of INFORMATION (1). It does not have the ability to be tied to external references such as the information source documents, but instead must rely on the internal constructions that have been inferred from verbal reports and observable actions of a problem solver.

INFORMATION PROBLEM (3.1)

As a reminder, information problem is the term which encompasses not only the information need but also the surrounding personal situation, including task. INFORMATION PROBLEM (3.1) has three aspects used by the problem solver: TASK (3.1.1), KNOWLEDGE (3.1.2), and SITUATION (3.1.3). Each of these structures attempts to capture a particular group of the problem solvers' knowledge structures about the information problem.

TASK (3.1.1)

The purpose of TASK (3.1.1) is to collect the knowledge about the task that the problem solver creates or uses. In addition to trying to fill a knowledge gap, the problem solver is also accommodating a particular assignment or job concerning that knowledge. In the study, the task was to produce a short written answer as a display of the knowledge that was constructed to fill the gap. Knowledge about the task was evident in the solution process in two aspects: PHYSICAL PRODUCT (3.1.1.1), which represents the artifacts that are produced during problem solving; and CONSTRAINTS (3.1.1.2), which depicts the restrictions or conditions associated with the task.

PHYSICAL PRODUCT (3.1.1.1) A number of physical artifacts were produced during problem solving. These consisted of intermediate products such as *Notes* and *Marks* as well as final products such as the *Answer* or the *Revised answer*. Each of these assisted the problem solver in some manner during completion of the task to produce a written response to the information problem. If created, *Notes* and *Marks* were produced one by one, throughout most of a session. After creation, they were referred to both during the subsequent information use part of the session and during the writing portion. Although physical products exist and may be separately perceived by an observer, examples of their creation and use are shown to exhibit their role as knowledge structures of the problem solver.

Notes is the type used to represent the writing of a comment on a sheet of paper other than the information source document. In some cases, after their creation, written notes engendered interactions similar to those displayed with information source documents. That is, they were read, marked, considered and in general treated as information sources.

> <u>*Notes*</u>:
> "[Writes note] [inaudible] in recognized excellent in writing nonfiction for children" [Resulted in note recorded on a sheet of paper that read 'Orbis pictus Award promote and recognize excellence in writing non-fiction'] (b19.1536.25)
>
> "[Writes and revises note] Menus, functions operation, instant availability, on screen help, text. *This is good point. On screen start up. Colon on screen, what am I? On screen help to assure -- on screen help -- on screen instructional help. That's good.*" [Resulted in note recorded on a sheet of paper that read '*Startup: On screen ~~help to as~~ instructional help*'] (a5.1213.14)
>
> "[Reads a document] Computer is accurate, coming form, software [inaudible] layout. *Okay. So we're talking about -- let's go back. Stop.* [Reads and marks (underlines) notes] *Automatic selection of terms. Okay. What did we want? So far we want time saving. What do we want the program to do? We want it to sort. We want it to check. We want it to list page references, page references, and we want it to print. We want it to alpha-arrange. No that's sort. Alpha -- what else do we want? . . .*" (a5.1230.23)
>
> "[Looks at notes] *Well, let me see what I've got here from my notes. Good things and bad things.*" (a4.1529.3)

The type *Marks* consist of marks made on a document by the problem solver. Examples of *Marks* are not readily demonstrated. In lieu of viewing the marks on the document itself, the best that can be done is to describe the kind of mark made and to indicate what kinds of things were marked. *Marks* consisted of such objects as underlines, circles, highlighting, and margin comments or symbols. They distinguished sentences, quotations, subheadings, words within a sentence, parts of *Notes*, and parts of *Problem statements.*

Problem solvers sometimes used only *Notes*, sometimes only *Marks*, sometimes both. The use of one did not seem to preclude the use of the other.

Answer and *Revised answer* refer specifically to the written response produced by the problem solver whereas knowledge to create these products is represented in other structures. *Answer* is used to represent the written response that the problem solver considered to fulfill the task of producing a written answer. *Revised answer* represents the intermediate form or forms of the written response that the problem solver produced during the session. The production of *Answer* or *Revised answer* was usually, but not always, concentrated at the end of the session, as one would expect, and did not consist of a single act but rather a series of interactions. For some problem solvers, *Answer* consisted of a single document that became the *Answer*; for others, a number of intermediate drafts were prepared and worked on, giving rise to *Revised answer*, before *Answer* was produced.

The existence of a written response and the fact that some problem solvers spent time and energy to revise it are of more interest to this study than the actual content of the written response or even the process of producing it. In as much as this study concentrates on interacting with information in a source, the final written response is outside its main interest. Because of this and because displaying *Answer* and *Revised answer* are difficult to do, no attempt will be made to present examples of these products.

CONSTRAINTS (3.1.1.2) CONSTRAINTS (3.1.1.2) consists of those restrictions that apply to the problem solving activity. In most problems, in addition to developing a path of operations and states that comprises the solution, the problem solver must also accommodate certain restrictions on what may be done. Identification of applicable constraints may be easy or difficult. Compliance with constraints is expected if an answer is to be accepted. Playing the game not only requires developing a solution but also demands that the solution be developed in accordance with existing conditions. In almost all incidents of information problem solving, there are some constraints. They may vary among situations and the consequences of ignoring them may differ as well.

As would be expected, in the situation used in this study, most aspects of CONSTRAINTS were identified in the early portion of the problem solving session. Three aspects were identified: TIME (3.1.1.2.1), ANSWER (3.1.1.2.2), and RESOURCES (3.1.1.2.3). The combination of these aspects set certain boundaries on the activities of the problem solver and on the expected result of the problem solving session. Knowledge of these constraints primarily derives from the "Start up" portion of the session and is based on the instructions of the researcher and the written problem statement. Although instructions and the problem statement were essentially the same, interaction between researcher and each problem solver opened the opportunity for individual conceptions of the constraints, as well as other parts of the information problem.

TIME (3.1.1.2.1). One aspect is TIME (3.1.1.2.1). Only one type was exhibited, called *Session length*. As with many problem solving sessions, this one was not able to extend indefinitely. In fact, the bounding time for a session was the length of the video tape, which could accommodate about two hours of recording. In one case, a need to relinquish the recording equipment after an hour put a shorter limit on the session. Length of session was not always specified in terms of time measurements. More typically, as shown in the first example below, the problem solver determined session length via his or her pace. Also, it should be noted that *Session length* affects PROBLEM SOLVING STRATEGY (3.2.1) type *Time*, which will be discussed below.

> *Session length:*
> "[During delivery of instructions at the beginning of the session] You are supposed -- just work at your own pace. And when you get done just let me know . . . ." [Response delayed until completion of instructions] (b19.1532.16)
>
> "[Researcher informs subject about near term time limit] This tape is going to run out in about 15 minutes.
> Subject: *Okay. I should be closing up soon.*" (c18.2043.4)

ANSWER (3.1.1.2.2) ANSWER (3.1.1.2.2) was constrained in two ways: *Answer form* and *Answer length*. *Answer form* represents the required presentation of a written answer that the external agent, i.e., the researcher, requested at the time of the assignment. The requirement for a written response was reaffirmed by some of the problem solvers toward the end of the session.

> Answer form:
> "[Oral instruction and delivery of written problem statement at beginning of session] . . . to write a half page or so . . . ." [Response delayed until completion of instructions] (c8.1049.15)
>
> "[Question addressed to researcher near end of session] *Should I actually go ahead and start writing something or* --
> Researcher: Any way you would normally do your work, go ahead and do it.
> Subject: *So you want me to go through the actual writing?*" (c8.1058.25)
>
> "[Question addressed to researcher near end of session] *Did you really want me to go ahead and finish writing this up? I have all my notes.*" (a5.1242.21)

Answer length specified the requirement for a one half page answer. Both length and form requirements were delivered to the participant in oral and written form.

> Answer length:
> "[Question addressed to researcher at beginning of session] *Do you want me to really go through the whole thing and have a half a page or so written?*"(c17.1355.8)
>
> "[Toward end of session] *I think I'm over half a page, but that's because I'm listing. If it were a paragraph it wouldn't be quite so long. But I'm almost through.*" (a4.1534.20)

RESOURCES (3.1.1.2.3). RESOURCES (3.1.1.2.3) exhibited two types of constraints: *Resource availability* and *Personal property*. *Resource availability* expresses the fact that the only available information sources were those provided by the researcher.

> Resource availability:
> "[Looks at set; responds to researcher instruction concerning 'Any questions?'] *And it's expected that we read*

every one of these ? Researcher: No, it's expected that you answer the question. *Oh.*" (b16.1215.16)

"[Oral instruction and delivery of written problem statement] Now the problem today -- the assignment for today is to use this material, that I provided on this little pile over here, ..." [Response delayed until completion of instructions] (c8.1049.13)

Personal property refers to the fact that each participant was informed that they had received a personal set of materials and were free to mark them if they so desired.

Personal property:
"[During delivery of instructions and materials] You may use the material before you on the table and you may write on the documents if you wish." [Response delayed until completion of instructions] (b1.1326.12)

"[During delivery of instructions and materials] You can use the material, you can write on this, if you prefer, you know, circle it or underline, whatever you want --
Student: *Write on here?*
Researcher: If you want." (c17.1353.19)

KNOWLEDGE (3.1.2)

The structure KNOWLEDGE (3.1.2) is intended to display the knowledge of the problem solver as it relates to the information problem. It is this structure which represents the results of interactions about the problem that existed or is developed by the problem solver.

The two aspects of KNOWLEDGE that were developed were TOPICAL (3.1.2.1), to represent the knowledge about the subject of the knowledge need, and WORKING CONSTRUCTIONS (3.1.2.2), to cover the ongoing mental constructions that facilitate the building of knowledge in response to an interaction.

TOPICAL (3.1.2.1). TOPICAL (3.1.2.1), which is knowledge about the topic of the need, is an aspect that is difficult to track in detail or depth. Each problem solver did produce an answer, indicating that knowledge about the information need, specifically the topic, was developed. References to topical information expressions abound in interactions. After all, the problem solver's main activity is reading material that is about the topic. References to topical knowledge are illustrated in two types in the reports: *Preexisting* and *Developing.*

Preexisting is used to indicate that the problem solver relates the information to personal previously constructed knowledge or experience. A few examples follow:

> <u>*Preexisting:*</u>
> "[Reads a document] And there would be at least one photograph at every page instead of two or three. It would be large, *and this is all in keeping with the trends that I've seen, too, in nonfiction books where they're full of illustrations and don't have too much text thrown together.*" (c17.1419.23)
>
> "[Reads a document] Page after page of stunning full-color pictures. Why are they beginning to illustrate them in full color when they always claimed they couldn't afford it. [inaudible] so they can't afford not to. *I know the other reason, they get them printed in the Far East, which they didn't use to do. So everyone is used to color television, of course. That's the first time I've seen this mentioned here, but that's what I've seen mentioned before in the past, is that a lot of this trend has to do with like* [sic] *they're trying to make books compete with television which is such a visual media* [sic]. *So they're trying to -- since there is a market consideration.*" (c17.1422.14)
>
> "[Reading a document] The first is a trivial problem, *the first* is that relationship between the number of items to sort and the time taken to complete the task. *I'm trying to apply this to when I did the back-of-the-book indexing. I assume that means the more -- the more items there are the longer it's going to take.*" (b2.1654.6)

"[Reads a document] *Okay.* It says the Word Perfect can do that. *I didn't know Word Per -- I use Word Perfect.* [inaudible] *Word Perfect. I didn't know it would do any of that.*" (b2.1724.10)

"[Reads a document] Visual look of nonfiction is especially important today. *This is reminding me of those -- what are they called? The close-up series, those books that have* [sic] *all full of photographs that are so beautiful. So how do you create a book like that is the question posed here.*" (c17.1421.14)

Developing indicates the interactions that overtly identify some accretion of knowledge about the topic of knowledge need and indicate clearly that items are of value for the answer. There is a definite overtone of connection to the knowledge gap or problem. Examples follow.

<u>*Developing:*</u>
"[Reads a document] A good way to do that is narrative. Is only one of the piper's tunes. *Okay. So that's one. We found out one. So we'll just put this down as the piper's tunes. Write this out. One would be narrative.* [Writes a note] *Okay. Good.*" (c18.1914.14)

"[Reads a document] Such a technique is particularly suitable for periodical indexes where the same cross-references may be required in sequential compilations. *Okay. So cross-referencing would be another criteria to look for.*" (b2.1703.25)

"[Reads a document] During operation the package displays the text being indexed, and while the processing is going on the package informs the user of its progress by displaying a percent complete bar chart at the bottom of the screen. *Well, that doesn't seem very necessary.*" (b2.1756.1)

"[Reads a document] Index Maker runs on IBM, *okay. The compatibility of machines. Let me see, I guess that would be a major consideration. Machine compatibility.*" (a5.1200.14)

"[Reads a document] *So we need something that can* -- [Long pause] to construct the index strings automatically. Automatic extraction of index terms. [Writes a note] *That would be an important capability.*" (b1.1353.13)

WORKING CONSTRUCTIONS (3.1.2.2). WORKING CONSTRUCTIONS (3.1.2.2) is the name of the structure which gathers the mental assemblages that the problem solver creates or develops during problem solving and that facilitate the construction of knowledge and understanding. They may be temporary or may become part of the long term memory of the problem solver; it is not evident from the reports which fate awaits the content of any particular structure. These aspects are intended to identify intermediate processes and products; *Developing*, discussed above, is the type that represents the collected gap-bridging facets of knowledge. The reports of the problem solvers identified several aspects: PERTINENCE (3.1.2.2.1), SUMMARY (3.1.2.2.2), INFORMATION TEXT (3.1.2.2.3), and EXPECTATIONS (3.1.2.2.4).

PERTINENCE (3.1.2.2.1). PERTINENCE (3.1.2.2.1) was a construction which was created by the problem solvers to represent the usefulness or importance of one of two groups of information: an *Information expression* or an *Article*. It is a result of evaluating the expression or article which clearly indicates the expression or article as bearing on the matter at hand but does not indicate overtly its contribution to bridging the knowledge gap. PERTINENCE types are allied with *Developing* by their similarity in picking out relevant facets; they differ in degree of commitment and in specification of relationship to the answer.

Information expression refers to those interactions which address the value of a single expression of text.

> *Information expression:*
> "[Reads a document] Identical -- during this sort the package combines entries that contain identical *blank* so there are multiple page references, multiple page references. *That's good. Multiple page references to entries.*" (a5.1219.1)

"[Reads a document] Apparent speed. *They were more concerned with speed than anything.* Control codes. *Well, I don't see that really said anything too much.*" (b2.1757.16)

"[Reads a document] *Let's see.* Page preview of index page. Page -- *oh,* page number order. *That sounds good.* [Writes a note]" (b3.1523.4)

Article refers to expressions of pertinence that encompass the entire document or as much of it as has been read.

Article:
"[Picks up and reads a new document] *So we'll start here with this one by Jo Carr. It's definitely talking about nonfiction of children, so I'm on the right track as far as that goes. And it seems to fit in because it's talking about nonfiction that's dull, and nonfiction that's well presented. So I would say this is definitely a relevant article.*" (c17.1359.11)

"[Picks up and reads a new document] *Um. This article doesn't seem as helpful as some others might be.*" (a4.1519.11)

"[Reads a document] Extensive research literature on automatic indexing by all those researchers -- *um. This seems to be the wrong article to begin with.* [Continues reading document]" (b2.1705.25)

"[Reminded by researcher to think out loud] *I'm scanning a lot of stuff that I don't think applies to -- there are a lot of examples of how people have used these principles to create appealing, informative books for children.* [inaudible] *the rest of it obviously doesn't seem to be pertinent. Okay.*" (b19. 1549.23)

SUMMARY (3.1.2.2.2). SUMMARY (3.1.2.2.2) is intended to indicate that synopses were developed to aid in comprehending the mass of information that was being taken in. Creating a summary may contribute to or serve as the basis of evaluations, whose results are sometimes expressed as pertinence judgments. A summary is focused on creating an aggregate of main ideas rather than on evaluation of the result, though an expression of assessment might be included, in which case it might seem to be merely an extended example of PERTINENCE for an information expression. But, the element of aggregation and the lack of an indication of contribution to the problem solution distinguish the two. Only one type of SUMMARY is identified: *Summary.*

> Summary:
> "[Sets aside document; looks at notes] *Good points came out of that document. One, about the speed, machine compatibility, alpha-indexing, which is standard. Material formats of various -- various material formats. Text display during indexing. I like that feature. Message to cue operator. Control codes. Control codes cueing operator as to machine function -- machine F* [inaudible]. *Okay.*" (a5.1208.12)
>
> "[Reads and marks a document] Exciting nonfiction. The style, clear, simple and vivid and also enthusiastic. *So the gist of this article is that it's the style of writing which is the most important aspect of making nonfiction books appealing.*" (c17.1403.19)

INFORMATION TEXT (3.1.2.2.3). INFORMATION TEXT (3.1.2.2.3) is intended to show the constructions that seemed to be elicited by an evaluation of the information text as text. The comprehensibility of the text is one key variable in building knowledge from written information. In one way, any evaluation exhibited would be engendered by the text; but in some cases, some of the constructs that are shown seem to address the text itself.

The types that were displayed were *Scope of article, Clarity of expression,* and *Validity of expression.*

Scope of article identifies those interactions that seem to center on the article's type or purpose. It differs from *Summary* by its focus on a type of document.

<u>Scope of article:</u>
"[Picks up new document] Index at Low Cost Indexing. *Oh, I think this is a review.*" (c8.1055.13)

"[Looks over set; reads titles] *Index-it. Index Aid. Those must be actual products. Macrex is another product. What's Ahead -- okay. This one seems like it's a little more of a general overview. Getting Started. This one is more of an overview. Index-Maker. That one sounds like a specific product.*" (b2. 1648.9)

Clarity of expression represents the problem solvers' concern with the relation between the way in which the author has presented material and the reader is understanding it, with emphasis upon its lucidity.

<u>Clarity of expression:</u>
"[Reads a document] Since the process itself was automatic, perhaps this display was meant to keep the operator -- *what is he talking about? Display of -- go back, go back. Where is it? The process -- no, where is the text display?* Reasonably no purpose seemed to be performed by having each word displayed while indexing was ongoing. No use -- each word displayed. Each word. *I'm not sure if he means the running list of words. That's confusing. That's not clear.*" (a5.1204.3)

"[Reads a document] Facilitate reference to specific items. *Okay, that's pretty clear.*" (b2.1650.18)

"[Reads a document] *Actually, maybe he's talking about information books. Well, I don't know, this first paragraph doesn't seem to be just talking about nonfiction, but then in the next one* [sic] *starts out,* there's more to an information book, *as if that is what our topic is. I don't think this is very clearly written.*" (c17.1413.12)

"[Reads a document] *Okay.* [inaudible] *that's interesting. I like the way this one is written because it's organized. That's what we're talking about. It really makes it clear.*" (c18.2015.21)

Validity of expression addresses the problem solvers' beliefs in the truth or falsity of information expressed in the text. This construction is reserved for overt expressions of truth or falsity and does not include other expressions of quality, i.e., "It's good;" of agreement, i.e., "I think so too;" or of approbation, i.e., "I like that."

> Validity of expression:
> "[Reads a document] There is no analysis of the text, no gathering together related information, no ability to produce subentry level. *Tis truth, tis truth.*" (b1.1405.17)
>
> "[Reads a document] There is a publication -- textbook publishers trying to appeal to everyone and send nobody to up and reduce ideas to homogenized pulp. *How emphatically true that is.* (c17.1441.21)
>
> "[Reads a document] *Let's see. This one says what we need, let's see if they're right. Um. Oh, I don't think so.*" (a4.1522.12)

EXPECTATIONS (3.1.2.2.4). EXPECTATIONS (3.1.2.2.4) is the structure which indicates that the problem solver anticipates upcoming information in the text. Only one type is developed, called *Expectations. Expectations* as a type is an inference about what is going to occur based on information that has been taken in. A few examples follow.

> *Expectations:*
> "[Reads a document; silent reading] *So far I haven't seen anything specifically about alphabetizing and how they handle the indents, but I assume if it's an indexing program it would take care of that.*" (a4.1524.4)
>
> "[Reads a document] Proof to the contrary is found in every good book of children's nonfiction. *Here he's going to talk about how contrary to what some people say, good nonfiction books can read like a story with a climax and suspense and so on.*" (c17.1432.25)
>
> "[Reads a document] So starting with accuracy, slash authenticity. *Got to be accurate. Got to be authentic. I'm sure this is what this is going to say in so many words.*" (c17.1456.4)

SITUATION (3.1.3)

SITUATION (3.1.3) captures the problem solver's knowledge about his or her surrounding situation and circumstances. In particular, the intent is to display the circumstances at the time of the problem solving session. The aspects that are identified are those situational factors that exist by virtue of the subjects agreeing to participate and the convention that the researcher establishes the conditions of the participation. The situation factors are relatively static features, identified via inference based on the delivery of instructions and materials rather than overt mention in the problem solvers reports.

Three types are distinguished, all of which were established at the beginning of the session. These are *Materials*, *Place* and *Time*. *Materials* included the supplies that were made available to the problem solver, such as pen and paper. *Place* highlights the fact that all sessions were conducted in a room at the School which the participants attended as graduate students. *Time* identifies that the session was conducted at an appointed time agreed to in advance by the participant and the researcher.

This particular structure garnered little attention from the problem solvers during the problem solving session. No overt mention of these factors was discovered in the reports. Apparently, once a participant agreed to be a subject, he or she was prepared to accommodate the situation that resulted.

WORLD KNOWLEDGE (3.2)

WORLD KNOWLEDGE (3.2) is concerned with knowledge held by the problem solver that is not related directly to the information problem.

This is of course a vast array of concepts and experiences arranged idiosyncratically by each individual. Concern here concentrates on the parts of this knowledge base that the problem solver finds salient during interacting with information. It does not represent the totality of a problem solver's knowledge.

WORLD KNOWLEDGE has two aspects that appeared in the verbal and action reports. One was PROBLEM SOLVING STRATEGY (3.2.1) and the other was SELF KNOWLEDGE (3.2.2).

PROBLEM SOLVING STRATEGY (3.2.1)

PROBLEM SOLVING STRATEGY (3.2.1) captures the structures resulting from the strategic part of problem solving. Problem solving strategies are acquired through experience with similar problems. As mentioned before, participants in this study have had many experiences with this particular problem solving situation. Their reports indicated use of several types of strategies, thus giving rise to knowledge structures of *Plan*, *Progress*, *Goal*, and *Time*. What is intended by this group is the result of the strategic action. Actions themselves are better captured in operators which are developed in a different structure.

Plan is meant to represent the problem solver's understanding of a course of anticipated actions or a method for accomplishing a goal. *Plan* represents the results of an action by a problem solver which develops a plan, such as might result from strategizing (a behavior embodied in an OPERATOR (2.1) to be discussed later).

Examples of each type are shown below.

Plan:
"[First action following instructions from researcher] *Well, first I'm going to scan these things to see which ones seem to*

have the most pertinent information, and also to find out a little bit more about the author and the credentials regarding this topic." (b19.1533.14)

"[First action following instructions from researcher] *So I'll start with the top one. How many are there? Four, five, six, seven.*" (c8.1051.13)

"[Action following writing notes] *Let's see. I'll put SA for stand alone, merging of terms to one entry. I'm going to have to go back through and remember which of these were for stand alone and which of these were for text entry.*" (b2.1739.12)

"[Reading a source] *Okay. This looks like some things that are coming up in the indexing field. Well, should finish dealing with the present first.*" (b1.1348.9)

"[Picks up new document] *And now* Jones, Getting Started. *This is April '86. I don't think I'm going to read all of this one.*" (b3.1543.5)

"[Picks up new document] *I think I'll stick with this one. So each of the sections after the first one -- no, after the second -- first and second one talk about things that software should be able to do. So maybe it should be approached under these headings.*" (c8.1058.20)

Progress is used to capture the problem solver's general sense of his or her status in moving toward an end or goal.

<u>Progress</u>:
"[Looks over notes] *Okay. So we've got some things there that might define what a good nonfiction book should be. Place to start this evaluation, or what it should be.*" (c18.1918.9)

"[Looks over notes] *Okay.* Cross referencing checking. *Have that. The global search for editing. Where did editing go? Well, this seems to cover the same thing that we covered in other articles.*" (b1.1409.22)

"[Looks at problem statement] *Okay. Let's see where I'm at here now.* Write a half page of so about the important capabilities for software which is used to create a back-of-the-book index. *Okay. And almost all the features that I came up with are for both stand alone and text file. Okay. How am I going to organize this?*" (b2.1758.21)

"[Sets aside document] *Okay. I can see what I'm doing here is I 'm going through them without taking any notes. But what the hell.*" (c17.1424.20)

"[Reading a document] *It's exactly what it was saying in the other one. I should probably have taken notes when I went along here, but I don't have a single note written on my piece of paper. Too bad.*" (c17.1455.15)

"[Reviews notes] *Okay. Now let's see if I've -- I'm looking at the ideas that I 've already wrote* [sic] *down on paper.* [Long pause]" (b19.1631.21)

Goal is intended to represent a specific end or objective established by the problem solver. *Goal* and *Plan* are distinguished since *Goal* represents an objective whereas *Plan* represents a method.

Goal:
"[Reading a source] *So all they're really talking here about* [sic] *is the mechanical for layout and format pages. Okay. Oh, so I got to remember I'm looking for criteria for indexing software. Okay. Let's see, does it give any problems with layout?*" (b2.1659.8)

"[Putting aside a source] *Well, look and see what we've got here and put it in a form we can read.*" (b1.1413.13)

Time is meant to capture the participant's ongoing awareness of time, both of its passing and of its remaining availability.

Time:
"[Following delivery of instructions at beginning of session; picks up document]
Subject: *I'll begin by reading* Literature of Fact. *Do we have time to read this?*
Researcher: Yes, you have until -- I would say about an hour.
Subject: *Okay.*
Researcher: Actually you can do it at your own pace if it takes you a little bit longer. The only thing, unfortunately, there is someone waiting to use the camera, which is not usual.
Subject: *Okay.*
Researcher: But [inaudible]. She said an hour would be fine. I mean a little after one would be fine.

Subject: *I'm going to underline some parts of this article that I feel would be answers to the questions being asked. At the moment I'm trying to read this as quickly as possible because I realize I don't have the time to read all of these, and being the type of person that I am, will try to read them all."* (b16.1217.25)

SELF-KNOWLEDGE (3.2.2)

SELF-KNOWLEDGE (3.2.2) concerns what problem solvers indicate knowing about their own knowledge. Metacognitive knowledge was shown about two different types of knowledge: *Cognitive style* and *Grammar*. Each is shown in examples below.

Cognitive style is the type which reflects what a problem solver knows about his or her own mental style and preferences. It is intended to capture interactions that indicate that the problem solver is taking into consideration his or her strengths or limitations. In the *Cognitive style* examples below, verbal reports indicate that problem solvers are aware of their preferences and limitations in terms of task requirements and quality of information.

Cognitive style:
"[Reads a document] *I'm going to underline some parts of this article that I feel would be answers to the questions being asked. At the moment I'm trying to read this as quickly as possible because I realize I don't have the time to read all of these, and being the type of person that I am, will try to read them all.*" (b16.1218.15)

"[Reads a document] *Oh. Okay. It's talking about ASCII, so I guess it's trying to get a -- a consistent format for the sorting. This is pretty technical for me.*" (b2.1657.2)

"[Picks up a new document] Index Aid. *Okay.* Number of -- number of entries. *Okay. I don't know, I guess that could be a problem if you had a mammoth index to do. Um. Some of this seems fairly technical. I don't even want to think about it.*" (a4.1528.22)

Grammar is the type the concerns the problem solvers' reflections on their knowledge of English and its component vocabulary, syntax, semantics and pragmatics.

> <u>*Grammar:*</u>
> "[Writes a note] *Simple, clear, vivid and enthusiastic. Okay. The same stuff. Okay. Sure I spelled that wrong. I always spell that wrong. E-N-T-H-U-S-I-A-S-T-I-C. Okay.*" (c18. 1939.19)
>
> "[Writes a note] Alphabetizes, concatenating the pages when index entries are the same, *and I guess that's another thing that it should do. Concatenate. Concatenate. Boy, that's hard to spell for some reason. Concatenate the page number. Okay.*" (b2.1733.2)
>
> "[Reads a document] So for instance, opening paragraphs and opening sentences within paragraphs are especially written for potential index entries. *Okay, that's a topic sentence. Topic paragraph. Yeah.*" (b2.1706.15)
>
> "[Reads a document] Two rhetorical devices should be avoided are teleology and anthropomorphism. *Don't know what teleology is.*" (c17.1457.20)

<u>Frame Branch INTERACTION (2)</u>

The third aspect of the overall frame of INTERACTING WITH INFORMATION is that of the INTERACTION (2) itself. Figure 4.4 shows the frame branch INTERACTION.

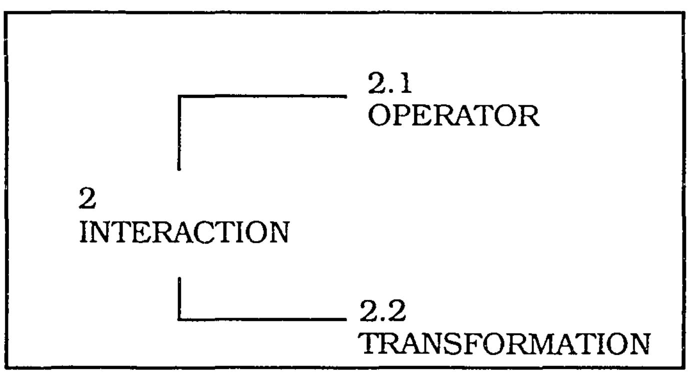

Figure 4.4. Frame Branch INTERACTION

INTERACTION (2) consists of the active process in which the problem solver performs some behavior, captured in OPERATOR (2.1), which in turn has an effect, captured in TRANSFORMATION (2.2), on some INFORMATION (1) or SOLVER'S KNOWLEDGE COMPONENT (3) structure. An OPERATOR is a name for a group of behaviors which the problem solver has used to move from one state to another. TRANSFORMATION represents the results of an OPERATOR upon the problem solver's knowledge structures.

This branch of the model concentrates on dynamic operators rather than on quiescent products. It is possible that the different senses of the word *structure* might cause some confusion, particularly when the discussion is about dynamic aspects of the model. Structure as used in this chapter refers to the hierarchy of components (a branch for example) and the slots (DOCUMENT for example) of the model. INFORMATION is considered a structure as is SEED within it. At the same time, in spite of its more active nature, OPERATOR is also considered a structure, since it is an aspect of the frame in the same sense that INFORMATION is. In both cases, structure is used to refer to a component or constituent of the frame, whether that designated structure serves as a product or as an operator.

OPERATOR (2.1)

OPERATOR (2.1) represents the action that the problem solver takes to move from one state of knowledge to another. It is the transforming deed.

Types found in OPERATOR are groups of behaviors, where behavior is the particular way that a problem solver acts or conducts himself or herself. (Behaviors will be underlined in the text to distinguish them from normal usage of the same words.) Grouping different behaviors into an OPERATOR is done to bring together transforming acts that are similar in purpose or effect. Behaviors may be either actions or cognitive events. In the case of an action, the behavior is readily observable as movements in the record. In the case of a cognitive event, the event is either inferred from or reported in the verbal record.

Because OPERATOR not only uses and affects structures both from INFORMATION (1), shown in Figure 4.2, and SOLVER'S KNOWLEDGE COMPONENTS (3), shown in Figure 4.3, some of the examples may reiterate those given earlier. An IWI instance consists of a number of combinations of operator and structure, called interactions. Operator and structure have been separated for purposes of explaining the constituents, but both are found in an IWI interaction. Earlier, discussion concentrated on structures; here, the emphasis is on operators.

Eleven types were created from the behaviors exhibited in the reports: *Culling, Selecting, Assessing, Signaling, Ingesting, Pursuing, Anticipating, Synthesizing, Modifying, Grouping* and *Managing.* To illustrate each type, examples of implementing behaviors will be shown.

Culling

Culling is the operator during which something is attended to with evaluation and negative disposition is reported or displayed. Example behaviors include eliminating an information source or a piece of information, setting aside an object in use, and disagreeing with information in an expression.

One is not to suppose that eliminating actually deletes anything from the mind of the problem solver. Rather, it is considered to designate the information as undesirable for this particular information problem. Setting aside is the action of moving an object away from the center of attention. The effect of disagreeing is not easily determined; for most cases, it is considered to be a designation of undesirability as well.

Culling:

Eliminating:
"[Looks over set; reads titles] Macrex, low cost. Software capabilities. Capabilities for indexing. *I will not read index low cost simply because I don't see it as a capability for software creation. It would be a factor, but a secondary factor after determining what the software should -- the program should look like.*" (a5.1157.9)

Setting aside:
"[Picks up a document] *This one is called Filling Vases While [inaudible], but since it is also by Jo Carr, the author of Literature of Fact* [pause] *I'll put it down to see what Milton Meltzer has to say . . . .*" (b16.1236.12)

Disagreeing:
"[Picks up a new document; reads a document] *I'll have to disagree with this in what the author says, . . .* " (b16.1234.13)

Selecting

Selecting is the operator during which something is attended to with evaluation and positive disposition is reported. Examples include behaviors such as choosing an item from among a number of items, agreeing with a piece of information, liking a piece of information (indicating a favorable attitude toward an item), spotting a piece of information that may be part of the solution (an overt comment or action) and noting a piece of information by writing it on a separate piece of paper. In all cases, the behavior seemed to indicate that the problem solver was responding positively to the information in the IWI incident.

Choosing involves focusing on one of a group. Agreeing and liking are signaled by explicit remarks that indicate being in harmony with an information expression of an author.

Spotting and noting in particular relate the information to the knowledge need in an active fashion. Both indicate that the information that is being attended to has value for solving the problem and is, in one case, actively recognized as part of the solution and in the other, is externally recorded for possible inclusion in the solution at a later time.

Selecting:

Choosing:

"[Looks at set] *Let's see. Which article is the shortest? I'm not sure -- well,* What's Ahead for Indexing Software. *That's probably ideal what they're trying to come up with. What we need -- um, ease of use. Let me put that aside.* Getting Started in Computerized Indexing, *maybe that's where I should start. Okay.* Automatic indexing from word processor text. *See if any of this fits what I've got so far.* [Reads last named document] (a4.1516.9)

Agreeing:

"[Reminder to think out loud] It's saying automation has been applied to routine tasks of filing and sorting and printing, but the extraction of entries is more problematical. *Exactly, because that isn't a mechanical process.*" (b2.1649.1)

Liking:

"[Reads a document; writes a note] *Number two, I like also this comment by the author which says* thinking should create a challenge. *I also like this, that this* thinking should begin as a curiosity." (b16.1220.11)

Spotting:

"[Reads a document] The package vendor claims that the Index Maker is fast and can index more than a page per minute. This may be the case when certain computers are used. *Okay. I have computer machine compatibility is a factor. Um.*" (a5.1205.14)

Noting:
"[Reads a document] A good way to do that is narrative. Is only one of the piper's tunes. *Okay. So that's one. We found out one. So we'll just put this down as the piper's tunes. Write this out.* [Writes a note] *One would be narrative. Okay. Good.*" (c18.1914.14)

Assessing

Assessing is the operator during which something is attended with evaluation but no disposition is reported. It is the term for those behaviors which differ from *Culling* and *Selecting* by not expressing a particular disposition and is therefore more general in nature. Examples of assessing behavior include evaluating information; guessing or drawing a tentative conclusion or opinion about something; questioning self rhetorically about information in the source, which seems to indicate some evaluation of the information; and confusing, which indicates that the problem solver experiences confusion or a gap in understanding some information expression. These behaviors have the cachet of depending upon some kind of appraisal of information by the problem solver. Noticeably, with the exception of evaluating, the behaviors seem to be resolving an anomaly or curiosity that is evident to the problem solver. The result was to keep the problem solver moving through the document by allowing some resolution of the circumstance. Evaluating seemed to be elicited for positive appraisals as well.

Assessing:
Evaluating:
"[Reads a document] . . . *So -- and this a good summation by the author . . . .*" (b16.1232.13)

Guessing:
"[Reads a document; encounters a truncated word] Once a file of unsorted index entries have been accumulated -- *oh, so you just keep entering them randomly, then you hit a key,*

check entries for style, then it detects errors in the entries indicating line number and error *something -- oh, error types, I guess.*" (b2.1751.20)

Questioning:
"[Reads a document] One way of analyzing how the writers [inaudible] the piper might look carefully at the results. *Okay. So what are the results? . . .*" (c18.1911.21)

Confusing:
"[Reads a document] This sort -- *okay. So this is called sort. Do I have a sort function? Sort function. Is that a function or is that -- wait now. I'm getting confused between the technical part and what I'm trying to do in indexing, so just write it down.* [Writes a note] *Sorting. Put it in quotes and look at it later.*" (a5.1219.5)

Signaling

Signaling is the operator which groups behaviors which indicate attention to something but show no evaluation or disposition. It is a very general operation that does little more than indicate that a piece of information has been attended to. Examples of signaling behavior include marking a part of a document; and heeding or showing interest in or about something with little expression of content.

In the case of marking, it is possible that a somewhat different, more cognitively active operation than *Signaling* is going on. There is a case for considering that marking is like noting, and should be, perhaps, a behavior included in *Selecting*, the operation which attends to something with a positive evaluation and disposition. In some cases, this appears to be so, as the example for marking indicates. In other cases, the document is marked but no indication of an evaluation or disposition is given. Examination of various documents used by different problem solvers shows underlining and circling that are not verbalized by the problem solver. (Although it illustrates the more unusual case, the example shown for marking was selected because the participant does make a verbal report as well as an action.) Given that marking is usually done silently with no indication of value to the participant, the behavior is classed with *Signaling* rather than *Selecting.*

Heeding is a catch all group for the various expressions of notice that problem solvers seemed to make throughout the session. Numerous incidents of saying "Okay," "Well," "Humm," and "Let's see" occurred in reports from almost all the problem solvers. It is difficult to tell exactly what the expressions signaled. Sometimes, it seemed to indicate that the problem solver had completed reading an information expression and wanted to mark it as attended to; sometimes it seemed to indicate no more than that the problem solver was alive and well. Why a problem solver is flagging a piece of information seems more important than the act of doing it; but, sometimes, working with available information, it not possible to figure out why. If it is possible to infer its purpose or use, that use is preferred to the more generic classification *Signaling.* The example of heeding included below is the most basic one and also illustrates the phrase that seemed most prevalent. For other illustrations, just reread the many examples included in this chapter.

Signaling:

Marking:

"[Reads a document; reads a quotation in document] Teachers, librarians and readers must look for a literary distinction in nonfiction, [inaudible] where exist. [Inaudible] every time we sit down for the job. [Marks document] *This is something good that I would like to use. I'm going to circle it and put it over here.* [Sets aside document]" (b16.1242.13)

Heeding:
"[Reads a document] Alphabetizing [Pause] *um.* Alphabetization, although, the type of programming involved is trivial, the need for it is still sometimes ignored and results can be disastrous. *Okay.*" (b1.1350.17)

Ingesting

Ingesting is the operator that groups actions that bring in or acquire information. For IWI incidents, this is not only a basic but also an ubiquitous operation. Every IWI instance includes the intake of information. The behaviors that comprise this type are reading an information expression; receiving materials; listening to oral instructions; and remembering, which is essentially retrieving knowledge from memory.

In many of the examples that have been given in this chapter, *ingesting* has been specified with the behavior action of "Reads a document." This is an implementation of reading, which actually relates to an expression of information rather than a physical source. Of course, many problem solvers repeated what they were reading in their reports, since reading includes attending to the written stimulus in working memory. But, many read silently. Silent reading is as much *Ingesting* as verbalized reading. It is not as clear what information was acquired, but it can be inferred that some was.

The existence of listening and receiving were determined from visible actions on the tape. The listening example below consists of a situation in which the problem solver has asked a question and responded with a conversational signal, and thus may be assumed to be attending to the answer. Receiving was not only visible on the video tape but also was evident in the researcher's instructions and actions of presenting information sources and problem statements.

Remembering seems slightly different from the other *Ingesting* behaviors. Remembering indicates the call up of knowledge already held by the problem solver; the other behaviors acquire knowledge from external, public sources. Remembering is included here in order to highlight the fact that some, although not all knowledge held by the problem solver is brought into play during a problem solving session. Although the knowledge base of any one person contains hundreds and thousands and millions of facts and experiences, all related in myriad ways, solving a particular problem calls for only some of that knowledge. At times, it is obvious from the protocol that stored knowledge is being called up. This behavior is included here to capture those instances of retrieval.

Ingesting:

Reading:
"[Picks up document] *I have to read the problem again.* [Silent reading]" (c8. 1102.1)

Receiving:
"[During start up of session]
Researcher: Now do you have any questions before we get started?
Subject: *No. Let's see. These are the things that you've selected?* [Looks at set]" (b19.1532.23)

Listening:
"[Researcher responds to subject's question]
Subject: *I can take notes, right, on this?* [Looks at set]
Researcher: Oh, sure, Yeah.
Subject: *Okay.*" (c18.1703.25)

Remembering:
"[Reads a document] Visual look of nonfiction is especially important today. *This is reminding me of those -- what are they called? The close-up series, those books that have all*

[sic] *full of photographs that are so beautiful. So how do you create a book like that is the question posed here."* (c17.1421.14)

Pursuing

Pursuing is that operation in which the problem solver actively goes after a particular piece of information. What is intended is to convey the spirit of chasing after something that is wanted or thought possibly to be available in the text. For some problem solvers, a piece of information or a summary will generate a search for a related and possibly existing piece of information. Examples of behaviors are asking the researcher for information and seeking information in a source. Asking occurred primarily at the beginning of the session, whereas seeking was found during the use of the information sources and of *Notes* during the writing stage. Seeking occurred not only for specific information but also for parts of a document, as the example for seeking shows.

Pursuing:
Asking:
"[During delivery of instructions at beginning of session]
Subject: *Am I actually going to write half a page?*
Researcher: Yeah, you should produce a written report."
(b2.1615.6)

Seeking:
"[Reads a document] *What else is this talking about? I'll look at the headings*: sorting, sorting of subentries, cross referencing, page number, concatenation, [inaudible] of entry level and concordance generation -- *here's* what is needed. *Maybe that's where I should go.*" (c8.1053.18)

Anticipating

Anticipating is the operator which captures behavior which expects something to occur or show up but does not involve active pursuit of what is expected. It differs from *Pursuing* by the lack of the quality of actively searching for the expected. Examples of behaviors are forecasting, in which the problem solver indicates that he or she expects something to occur or that a kind of information is likely to be found; and predicting, in which the future value of something is indicated. Forecasting is centered on the expectations of the problem solver that the author would include a particular kind of information. Predicting is related to the likely value of information for solving the problem, which value is determined before rather than after reading the document.

Anticipating:

Forecasting:

"[Reads a document] And let's look at some recent titles, it says, to help answer that question. Talking about Statue of Liberty Centennial, and books that were made around that. *And I'm going to skim this. I assume it's just going to be illustrating how these books include those four concepts that were outlined in the beginning.*" (c17.1421.19)

Predicting:

"[Sets aside a document; chooses a document] *This one is called* Filling Vases While [inaudible], *but since it is also by Jo Carr, the author of Literature of Fact* [pause] *I'll put this down to see what Milton Meltzer has to say about the* Possibility that Nonfiction of Writer's View. *I like Milton Meltzer, I've read many articles by him so this should be an interesting article.*" (b16.1236.12)

"[Reads a document; silent reading] *Here in the second half of page two we're getting into our subject at hand. So I should not throw this article away after all.*" (c17.1405.9)

Synthesizing

Synthesizing is the operator for the group of behaviors that indicate something is formed or created by bringing together separate parts. This operator's role is to recognize those activities of the problem solver that pull together in some way individual pieces of knowledge and/or information. Examples of behaviors of this operator are relating two things, in which two things are juxtaposed; comparing two things, in which similarity or difference is noted; integrating something with something else, in which things are interpreted or melded into a single result; summarizing information or other problem solving actions, including a behavior that condenses information into what are termed place holders; elaborating on information in a source by adding personal knowledge to it or putting it in one's own words; and commenting, which is saying something about the content of a piece of information or stating a belief or opinion about the information.

This OPERATOR is an excellent illustration of why behaviors are clustered, instead of being treated directly as the operators in the model. The various behaviors in this group appear similar and are difficult to disentangle. It is not easy to make the fine distinctions that are involved in differentiating these behaviors. By grouping the behaviors, however, the OPERATOR is able to represent the shared core, which is more than sufficient for the analysis. The choice of OPERATOR is less likely to be in error than the choice of behavior, since the common core will be represented regardless of the actual behavior.

Synthesizing:

Relating:

"[Reads a document] . . . Thinking then is important while intellectual context is basic [inaudible] and so is feeling. *That's true, that goes back to the statement made earlier in which you have to sit to think and to feel deeply, ...*" (b16.1223.12)

Comparing:

"[Reads a document] . . . *This is an interesting contrast, the selection which I had just read with this selection from Ishii, ...*" (b16.1226.14)

<u>Integrating</u>:
"[Reads a document] Here it says they're turning to printers in the Far East and Europe, *and that's what I was talking about, which I knew because I worked at Bishop Museum for this last year.*" (c17.1423.3)

"[Reads a document] Automatic selection of terms. *Okay. They're talking about stop lists which eliminate function words. Okay. I remember that from 670. Stop list words. And then they have -- they call them go list words, I never heard that, but that's clear, and those are descriptors, okay.*" (b2.1704.5)

<u>Summarizing</u>:
"[Reads a document; condenses information] *And they use it to index the first tasks of a four-page book, 158, da-da-da. Okay.*" (b2.1750.4)

"[Flips through a document] *Okay. This one has good topical headings as to what the program would have.*" (a5.1238.5)

<u>Elaborating</u>:
"[Reads a document] Grouping index entries. Grouping allows you to identify a particular group of records and work with them as if they were the only records in the entire index. *Oh, okay. Okay. I understand what that means. I don't know if I can explain it, but it's when you're following a particular train of subject and you want to make sure you're hitting every related item making global changes without worrying about messing up the entire index. Yes, I understand what that means.*" (b2.1712.22)

<u>Commenting</u>:
"[Reads a document] *Okay. Oh,* it reminds you after 105 entries that you should save. *That is a nice feature, actually. But, I don't know that it would be necessarily -- that's something you should be doing anyway.*" (b2.1754.2)

A brief comment about the place holder in the example of <u>summarizing</u>. The "da-da-da" used by the problem solver is called a place holder, because it condenses to a few syllables the material that the problem holder is <u>reading</u>. It indicates that something that exists in the text is being acknowledged but not necessarily read.

Modifying

Modifying is the operator which shows the problem solver changing something, particularly a written something. That is, the problem solver changes a document such as the problem statement or his or her notes from their value as presented to something else. Examples of this OPERATOR are distinguished by who created the object that is being changed. Editing is the changing of someone else's work; revising is changing one's own work. Editing was done very seldom, and as would be expected, revising occurred most frequently during the writing stage of the session.

Modifying:

Editing:

"[Reads problem statement] *So this might be software* -- using the materials provided -- [marks problem statement] *um, I'm going to cross out* using the materials provided, *okay,* want half a page about important capabilities for a software which is used to create back-of-the-book indexing. *Okay. What I have just finished, crossed out words that are insignificant, I want* half a page *and I want* important capabilities for software used -- *cross out* which is, *underline* used to create back-of-the-book indexing." (a5.1210.3)

Revising:

"[Writes solution] *Before -- before -- no.* [Marks just written word by crossing it out] *When one designs . . . .*" (a5.1243.4)

Grouping

Grouping is the OPERATOR that indicates that the problem solver is putting together some physical items. It carries the underlying theme of an operation that is assembling objects based on some rule, reason, or perceived similarity and at the same time separating the assemblage from other, non-qualifying objects. Included are the behaviors of enumerating, in which the problem solver counts the occurrences of some event or object; and sorting, in which a classification scheme of some kind is evident from the action of placing items together. Enumerating provides the problem solver with an knowledge of the magnitude of a group while at the same time implying an underlying basis for bringing the objects together. Sorting concentrates on the basis of the grouping and pays little attention to its resulting size. Bases of groups are not always obvious from the reports; in a few cases, remarks do provide some indication of the grouping premise.

Grouping:

Enumerating:

"[Reads a document] . . . Imagery. Tone of text. *Here is Lauper's Volcano mentioned for the third time. Everybody loves that book. . . .*" (c17.1459.12)

"[Reads and marks notes by numbering] *Let's see. What does this mean?* Single concept. Dramatic focus. Extended analogy. *Number one,* imaginative storytelling. *Two,* vivid description. *Three,* eloquent style. *Four,* graphic excellence. *Five -- let's see what the term is here.* [Reads a document]" (b19.1600.8)

Sorting:

"[Reads titles of set] *Okay. Let me see,* Software Tools for Indexing, what we need, *title.* Index it, low cost indexing, *title.* Index Aid, computer-assisted back of the book. Index Aid, *low cost, tools, money, aid. Tools, I'll put possibly tools together.* [Puts documents in two piles] (a5.1156.13)

Managing

Managing is the operator which shows actions a problem solver used to regulate and guide a session. This operator is a loose collection of behaviors which have the effect of handling session activities or objects. Examples of *managing* behaviors include strategizing about a future path; reviewing past events or activities; accommodating a physical factor; metacognitive thinking; and emoting.

Strategizing is a behavior which took into account different time frames, i.e., short term or long term, and may be applied to more than one kind of action. The reports show less evidence of concern for long term strategy than for near term choices of the action. Evidence for long term strategy development usually occurred early in the session whereas concern for near term choices occurred throughout the session. A strategy for an entire session was seldom articulated; most reported strategizing concerned near term actions about what to read next. A longer term strategy was seen which included sorting the information source set (a *Grouping* operation) with some indication of anticipated pattern of use.

Reviewing occurred in conjunction with strategizing at times, but it is difficult to specify the effect the review had on a problem solver's continuing actions. A review seemed to assist the problem solver in keeping on track, even if an overall plan had not been stated. Given that the participants had substantial experience with this kind of problem solving, it may be that they felt it unnecessary to spend much conscious effort on either planning or reviewing the steps, although they in fact did have a version of an overall sequence of activities.

Accommodating is a behavior exhibited in regards to some unchangeable problem encountered during the session, such as imperfections in a physical source. It shows a problem solver "making do" with what is presented and doing his or her best to adjust to it.

Metacognitive thinking is a behavior of thinking about your own thinking. Problem solvers did display attention to their own thinking occasionally. They were aware of their own predilections for handling a set of material and for recognizing that a vocabulary item is unknown, for example.

Emoting is evident in the protocols, more obviously in actions than words many times. Still, a burst of verbal emotion did happen, although not often. This behavior differs from heeding in degree or strength and in its focus on the problem solver's emotional state.

Examples of behaviors for *Managing* follow.

Managing:

Strategizing:
"[Reads a document; silent reading] *Well, I'll start by dividing the needs into two categories, the clerical ones and then the actual extracting.* [Picks up problem statement] *I have to read the problem again.*" (c8.1101.23)

"[Writes a note] . . . *Is that a function or is that -- wait now. I'm getting confused between the technical part and what I'm trying to do in indexing, so just write it down. Sorting. Put it in quotes and look at it later.*" (a5.1219.6)

Reviewing:
"[Sets aside a document; about to pick up a new document] *Okay. I can see what I'm doing here is I'm going through them without taking any notes. But what the hell.*" (c17.1422.20)

Accommodating:
"[Reads a document; encounters truncated word] . . . *Part of the article isn't to copy* [sic] *here so I'm kinda of* [sic] *making up what the word is that's missing at the end. Okay.*" (b2.1706.10)

Metacognitive thinking:
"[Writes a note] . . . *Okay. That's an incomplete thought that I know I made there. What do I mean? . . . .*" (a5.1208.3)

<u>Emoting</u>:
"[Reads a document] . . . We've talked about style, *which I have noted*. And the graphic excellence. *Oh, feel great.*" (b16.1232.19)

This completes the explanation of the structure OPERATOR (2.1). It is the basis of activity in the model, representing the implementation of actions to change states. The next structure, TRANSFORMATION (2.2), captures the effect an OPERATOR has upon the structures in the model.

TRANSFORMATION (2.2)

TRANSFORMATION (2.2) attempts to delineate what happened to a knowledge structure as a result of an OPERATOR being applied by a problem solver. One might consider that an operator might in fact name its effect as well as describe its implementing action. For example, *Grouping* and *Selecting* seem to indicate a rather precise and concrete result. *Managing*, perhaps alone of the types of OPERATOR, on the other hand, does not specify a particular effect. In spite of the seeming difference of the two, neither really pinpoints the effect on a structure of INFORMATION or SOLVER'S KNOWLEDGE COMPONENTS. For this reason, a type of transformation is specified for each interaction, which reflects the nature of the transformation that is realized and how the constituent structures are affected.

The types of TRANSFORMATION that have been chosen to depict an effect on the content of the structures of the solver's knowledge are similar to those found in the field of data processing. Creating a new knowledge base in a problem solver's mind seems to be similar to updating a file in data processing.

In the case of updating a file, there are usually three types of transactions: adding a new record, changing an existing record, and deleting an existing record. Of these, the only one that does not have a clear counterpart for mental knowledge bases is deleting. While it is clear that a concept or experience may be irretrievable, it is not clear whether they are ever deleted, if deleted is taken to mean removed from the knowledge base. Changing one's beliefs about a concept, or its verity, does not necessarily expunge the prior belief or truth value from one's mind. Human cognizers can and do hold, simultaneously, contrary and incompatible understandings about a belief or concept. Thus, acquiring information that reverses a previous position is not the same as actually removing it from one's store of knowledge.

Adding new knowledge and *changing* existing knowledge both seem reasonable transformations for mental knowledge base maintenance.

Adding in mental knowledge base terms is not as clear cut as it is for adding in data base terms. In a data base, one just looks at the output to see if the record occurs. If so, then it was added. In mental operations, however, one can not just look. Thus, a particular concern is knowing if adding has occurred. Has adding taken place just in case one has read an item with new information? This seems unlikely, because it is possible to read the same document more than once and have the experience of encountering information that is not already part of one's knowledge. Since *adding* may occur implicitly, without the conscious attention of the problem solver, and since verbal reports of a problem solver will indicate attended to information only, then information that is unattended will be largely unreportable from working memory. The traditional method of knowing what someone knows is to test for the knowledge. This is not a viable option in the situation here for the obvious reason that the session was desired to be as natural as possible. Constant interruptions for comprehension or memory tests would be very unnatural.

For this study, the type *adding* will be used to indicate that something new has been constructed when it is inferable from the verbal reports of a problem solver that information that has not been salient previously has been attended to in working memory. Since just the fact of reporting does indicate existence in working memory, the short term effect is to add the knowledge to the problem solver's mental arsenal of knowledge. Whether it is retained past the processing time of working memory is not addressed here. That is, no test of comprehension is given beyond the production of the answer. Given that the problem solvers were able to and did use external storage devices such as notes, it is unclear how much of the answer would represent new constructed knowledge in the mind of the problem solver.

Changing is the type of TRANSFORMATION that covers all other effects from an OPERATOR. If a report indicates that attention was given to some piece of information, then an effect is judged to have occurred. If the effect is one that did not appear to involve new information and is thus classed as *adding*, then it is presumed to be one that changed some structure's content.

The fact that there is an effect is more important than the exact type of transformation that happens. Although effort is made to particularize the effects, recognizing the effect's existence seems more germane to the study's concern. In spite of the common understanding that adding and changing require some discernible signal or trace, a TRANSFORMATION of *adding* or *changing* will be inferred for every IWI, even if a signal is not present. The intent is to show movement toward a solution, and further to demonstrate that movement from state to state does occur with each IWI instance.

A third TRANSFORMATION symbol is used. The letter "I" is used for *informing*, or to indicate that a structure is acting as information. For example, reading an expression, or retrieving a memory both serve to inform through some structure, either INFORMATION in the case of reading, or SOLVER'S KNOWLEDGE COMPONENTS for remembering. It is useful to be able to identify this function and thus will be included in the codes for TRANSFORMATION.

INTERACTING WITH INFORMATION in Action

Now that the structures and operators of the model have been identified, it is time to show how the IWI model is used to depict IWI processing. To do this, three extended examples are developed, each of which contains several IWI incidents. These examples illustrate the interactions of the three major parts of the frame model and demonstrate the role of the structures that were identified in the previous section.

Model Caveats

The basic purpose of this model is to represent the mental structures employed by the problem solver and to show the cognitive operations that a problem solver applied to those structures. It is important to be aware of several implications of the model before examining it in action.

(1) Structures may be representative of both mental states and physical items, simultaneously. That is, for example, *Set of documents* (1.2.2) is both a set of physically existing documents, which are subject to the usual benefits and limitations of a physical object, and a mental representation of that physical set. The same model structure (i.e., terminating aspect INFORMATION.PHYSICAL SOURCE.CLASS (1.2.2) and type *Set of documents*) represents both of these. There is no separate structure for mental state about the physical object. They are co-represented.

(2) A problem state includes the entire mental and physical representation of the problem solver. The general problem solving approach assumes state changes; thus, it is useful to clarify what a state is in terms of this model. A state is not just a particular structure, but rather all the structures of the problem solver. Although operator transformations are tied to particular structures when viable, too much is unknown to exclude other effects on the state. So, problem solvers' initial states and final states, in problem solving terms, consist of all structures that are available to the problem solver.

(3) Information in a IWI incident may be followed by an response. That is, in fact, the operational definition of IWI. But, there is no assertion that the information causes the response. Because verbal protocols only report attended to information, not all information is available to the modeler. A problem solver is not always fully aware of everything he or she is experiencing.

(4) Because of (3) above, the model is demonstrated as a series of process-structure interactions. A direct input, process, output correlation

is not always clearly indicated for each IWI incident and its inclusive interactions. Transformation type is identified for an operator-structure pair. Each pair changes the state of mind of the problem solver -- some changes can be captured from evidence in the reports, some are not available to the problem solver directly.

(5) A word is needed about the relationship of IWI incidents and individual interactions. A single IWI has been defined as a combination of incoming information and its immediate response. This is a necessary definition in order to identify objectively the phenomenon in the data stream. However, the input and use of information during the reading of an information source is ongoing; a single IWI instance, defined narrowly as has been done, does not necessarily encompass a complete mental connection with the information that is taken in. As many of the examples in the previous section have shown, more than one IWI may be involved in achieving an integrated, coherent consequence from the information.

At the same time, more than one operator may be revealed in a single IWI instance. Humans appear to be frugal in signaling their intents and frequently indicate more than one operation with a single action. Sorting out this mix of interactions and IWI requires the observer to carefully examine the data *in situ*.

The IWI Grid

The frame model INTERACTING WITH INFORMATION (0) has three primary branches, each of which serves a function: INFORMATION (1) and SOLVER'S KNOWLEDGE COMPONENTS (3) for components acted upon; and INTERACTION (2) for process. Note that structures in

INFORMATION and SOLVER'S KNOWLEDGE COMPONENTS may be either input or output; their roles vary from interaction to interaction.

All that is needed to demonstrate the model in action is to choose an instance of IWI and to process it in the model. The procedure for processing an IWI instance is straight forward: (1) an IWI incident is chosen; (2) it is examined to specify the structures that are active; (3) the OPERATOR (2.1) or multiple OPERATORs are distinguished; (4) the intersection of structure and operator are identified; and (5) the TRANSFORMATION (2.2) for each intersection of OPERATOR and affected structure is determined.

Each of the above steps incorporates the use of the detailed *types* for the appropriate part of the model. That is, specifics for structures are derived from the types that comprise the terminating structures; OPERATOR, based on the behavior or behaviors that are present in the incident, is chosen from among the eleven groups that were developed; and type of TRANSFORMATION is chosen from its types.

The intersections of INFORMATION (1) and SOLVER'S KNOWLEDGE COMPONENTS (3) with OPERATOR (2.1) form a grid of the IWI model. Figure 4.5 shows the processing form of the model.

This form of the model shows how the branches interact with one another. The INFORMATION (1) and SOLVER'S KNOWLEDGE COMPONENTS (3) are input and/or output to INTERACTION (2), which has the role of process. A process, or processes, may use information to produce an effect (TRANSFORMATION (2.2)) on some structure in the model.

For display, a modified version of the processing form, called an IWI display grid, is used. A complete display grid is shown in Appendix B.

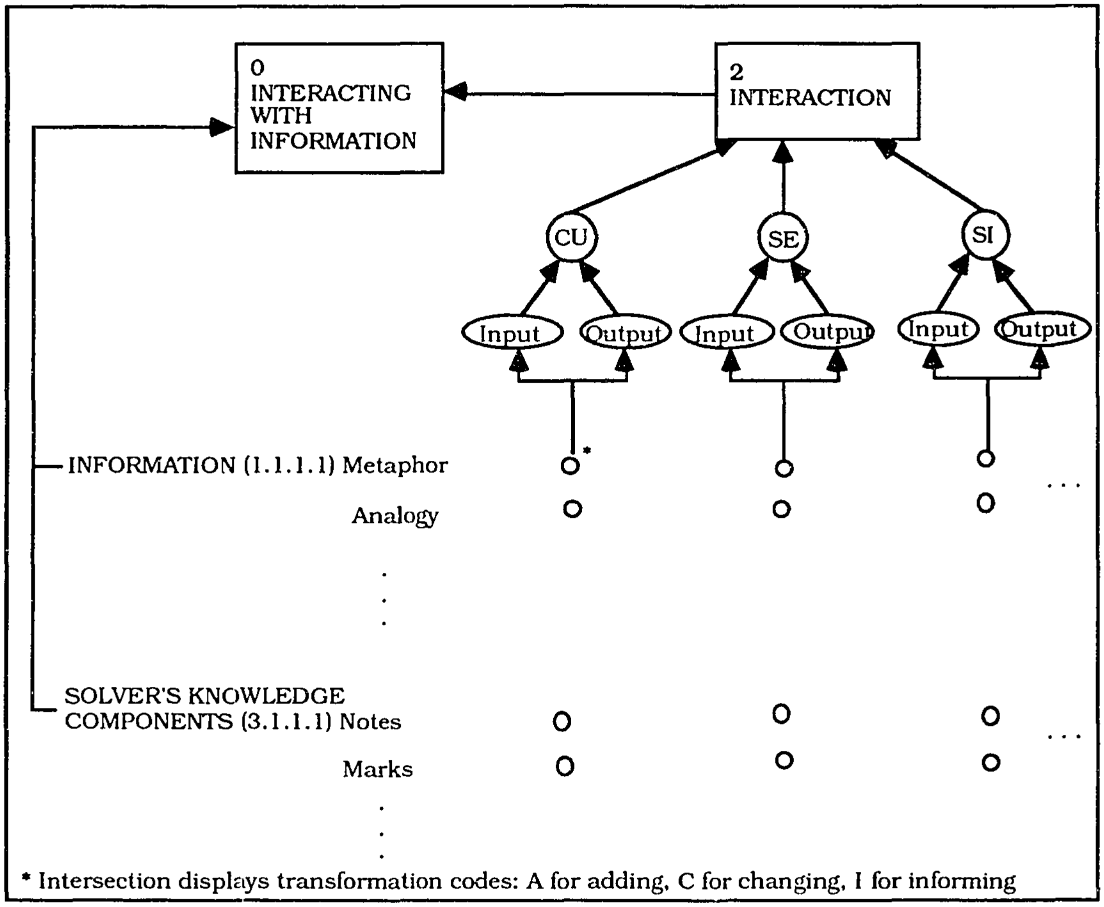

Figure 4.5. Illustration of frame model in processing form

An IWI display grid shows the interactions of IWI structures and operators with a condensed version of the INTERACTION branch. Condensed versions of the display grid are used to illustrate the examples, which, because of size problems with displaying the grid, do not show inactive entries for that example. The branches, aspects and types are listed in abbreviated form down the left side of the grid; each OPERATOR is listed as a column across the top. The circles in each column represent the intersections. TRANSFORMATION types are entered as I for *Informing*, A for *Adding*, and C for *Changing*.

Extended Examples of IWI in Action

Three examples have been chosen to demonstrate the component interactions. Each example follows the same sequence of presentation. A supporting verbal and action report for one IWI instance is quoted using the same conventions for displaying the part of the reports as have been used throughout this chapter. That is, information that is read is in plain text; participant's words in italics; and actions or researcher commentary are enclosed in square brackets. When the selection of protocol involves discussion between researcher and subject, RES will indicate the researcher, SUB the subject. The verbal and action reports for each example are presented IWI incident by IWI incident, but are to be understood to follow each other in the transcript.

Each IWI instance is examined in order to identify the appropriate structures and operations for each interaction contained in the IWI incident. Each interaction of INFORMATION and SOLVER'S KNOWLEDGE COMPONENTS structure and OPERATOR is determined and explained, and the respective intersection in the grid is completed.

Each verbal description of an interaction is accompanied by several devices to assist the reader in following the development of grid entries. Each interaction in an IWI incident is listed in an abbreviated form immediately following the IWI report. The abbreviated form has this structure: Terminating structure Branch and ASpect (BAS) number: Type: Operator: Transformation code. The terminating structure is shown by its BAS number only. Type is the appropriate entry from the terminating structure's valid *types*. Operator will use the first two letters of OPERATOR as a two letter code. Transformation code will be either A for *adding*, C for *changing* or I for *Informing*. Each interaction, numbered for ease of reference, is discussed briefly.

Each IWI incident is also accompanied by a tabular display, which illustrates the state of a grid after processing that IWI instance. A composite grid appears at the end of each example as a wrap up.

Example One - Starting the Session

The first example covers the start up portion of the problem solving session for one subject. It is approximately 2 minutes in duration, and consists of 6 IWI incidents and 19 interactions. (b16.1213.1). This is a typical start up for a session, and shows how the initial task and situation information are acquired.

IWI1.1

"RES: This is subject b16 [inaudible] backup in case it doesn't work. Okay. The problem that I want you to work on is the one that we talked about in class, which has to do with the development of children's and young adult's nonfiction as literary art. This is the statement of it. [Hands problem statement to subject] And what I'd like you to do is to use these sources that I'm going to give you here [Hands information source set to subject] and prepare a half page or so as an answer.

While you're doing that, you can use this [Points to tablet on table] and you can write on these documents, if you like.
SUB: *Okay.*

The following interactions were found in IWI1.1:

(1) 1.2.2:Problem statement:IN:I
(2) 1.2.2:Set of documents:IN:I
(3) 1.2.2:Oral:IN:I
(4) 1.1.2:Individual topic:IN:I
(5) 3.1.2.1:Developing:IN:A
(6) 3.1.1.2.2:Answer form:IN:A

(7) 3.1.1.2.2:Answer length:IN:A
(8) 3.1.1.2.3:Resource availability:IN:A
(9) 3.1.1.2.3:Personal property:IN:A
(10) 3.1.3:Materials:IN:A
(11) 3.1.3:Place:IN:I
(12) 3.1.3:Time:IN:I

Interactions 1, 2, and 3. The first IWI instance describes the task, both orally and in written form, and the information sources to the problem solver. One terminating structure in INFORMATION (1) that is affected is PHYSICAL SOURCE.CLASS (1.2.2). *Problem statement, Set of documents* and *Oral*, all types of CLASS, are recognizable as input. The problem is established in both *Problem statement*, a physical document delivered to the problem solver, and in the *Oral* remark of the researcher about the problem, to wit, ". . .which has to do with the development of children's and young adult's nonfiction as literary art." The *Set of documents* is seen in delivery of the documents by the researcher. The OPERATOR (2.1) that is evident is that of *Ingesting*, which describes taking in or acquiring information from some source; thus, each intersection is completed with the informing code, I.

Interaction 4. A second terminating structure of INFORMATION (1) is affected as well. The quoted remark and the physical document also establish the *Individual topic* of the problem, which is located in SEED.CONTENT (1.1.2). The same OPERATOR applies; thus, the intersection of *Individual topic* and *Ingesting* is also marked I.

Interaction 5. Using this information, the OPERATOR *Ingesting* also begins to establish the contents of *Developing* in the terminating aspect TOPICAL of the structure SOLVER'S KNOWLEDGE COMPONENTS.INFORMATION PROBLEM.KNOWLEDGE (3.1.2.1). (SKC will be used as an abbreviation for SOLVER'S KNOWLEDGE

COMPONENTS occasionally.) The topic of the information problem is now known, although there is not yet a determination of the knowledge gap that this problem solver will be tackling. In the grid *Developing* would show the TRANSFORMATION (2.2) code A, for the type *adding*, in the column for *Ingesting.*

Interactions 6, 7, 8, and 9. In addition, this IWI also established several CONSTRAINTS in the structure SKC.INFORMATION PROBLEM.TASK (3.1.1.2). *Answer form* and *Answer length* of ANSWER (3.1.1.2.2) and *Resource availability* and *Personal property* of RESOURCES (3.1.1.2.3) are all *added* by the OPERATOR *Ingesting. Answer form* was established by the written problem statement and is implied by the phrase that also establishes *Answer length*, that is, ". . . prepare a half page of so as an answer." *Resource availability* is set by the oral instruction to ". . . use these sources that I'm going to give you here . . . ." The constraint, or more accurately, the information that the documents are *Personal property* is seen in the instruction that ". . . you can write on these documents, if you like."

Interaction 10. It is in this IWI that the researcher indicates the tablet on the table and says ". . . you can use this. . .", thus identifying the *Materials* that are provided for the problem solver's use. This element is included as part of SITUATION in the structure SKC.INFORMATION PROBLEM (3.1.3). *Materials* is shown as undergoing the TRANSFORMATION *added* by the OPERATOR *Ingesting.* Its treatment differs from the other two types under SITUATION (discussed above) because it is mentioned orally as well as shown in an action.

It is the existence of the participant's response (*Okay*) that indicates that the information is being taken in. In this instance, the okay response is not interpreted as heeding but rather as selecting a response to the activities of the researcher.

Interactions 11 and 12. Note that the composite grid shown in Table 4.3 indicates three active types in the OPERATOR column for *Ingesting* (IN) for the structure SKC.INFORMATION PROBLEM.SITUATON (3.1.3). Although nothing appears in the transcript about two of these features, the mere presence of the participant at the agreed upon time and place are sufficient to instantiate *Place* and *Time*. Because they were established before this session began, they are indicated as being remembered or serving to inform; the intersections are marked with an I to indicate this retrieval.

Example One has acquired entries as shown in Table 4.1.

Table 4.1.
Effect of IWI1.1 on IWI Grid for Example One

BRANCH AND ASPECT	OPERATOR TYPE	CU	SE	AS	SI	IN	PU	AN	SY	MO	GR	MA
Info.Seed.Content (1.1.2)	*Individual topic*	O	O	O	O	**I**	O	O	O	O	O	O
Info.PhysSource.Class (1.2.2)	*Problem stmt*	O	O	O	O	**I**	O	O	O	O	O	O
	Set	O	O	O	O	**I**	O	O	O	O	O	O
	Oral	O	O	O	O	**I**	O	O	O	O	O	O
SKC.InfoPrb.Task.Cnstrt.Answer	*Answer form*	O	O	O	O	**A**	O	O	O	O	O	O
(3.1.1.2.2)	*Answer length*	O	O	O	O	**A**	O	O	O	O	O	O
SKC.InfoPrb.Task.Cnstrt.Resources	*Resource avail*	O	O	O	O	**A**	O	O	O	O	O	O
(3.1.1.2.3)	*Personal property*	O	O	O	O	**A**	O	O	O	O	O	O
SKC.InfoPrb.Know.Topical (3.1.2.1)	*Developing*	O	O	O	O	**A**	O	O	O	O	O	O
SKC.InfoPrb.Situation (3.1.3)	*Materials*	O	O	O	O	**A**	O	O	O	O	O	O
	Place	O	O	O	O	**I**	O	O	O	O	O	O
	Time	O	O	O	O	**I**	O	O	O	O	O	O

A = *Adding*; C = *Changing*; I = *Informing*

IWI1.2 and IWI1.3

IWI1.2
RES: Please think aloud as you do this problem, that is, you are to say out loud what is in your mind as you read the material and think about the problem. The purpose of thinking out loud is to record from your words what's going through your mind. Okay? Your spoken thoughts are data which I can use in my study.
SUB: *Okay.*

IWI1.3
RES: You may find that you read some or none of the documents aloud. If you do, it's not -- either way it's okay. Work as naturally as possible while saying out loud your thoughts.
I'll be here to keep an eye on the equipment. I have never convinced myself the equipment will work through [inaudible] and if I think that you're not -- if I think you're thinking and not talking, I'll probably ask you to be sure and think aloud, which I'll probably do some time when you're actually reading instead, but I'll try not to do that. The documents are coded only so I can catch them on the camera.
SUB: *Okay.*

The second and third IWI instances are concerned primarily with instructions about thinking aloud and the color coding of the information sources. Since these are not germane to a usual information problem solving process, they will not be analyzed.

IWI1.4

RES: They're not important otherwise. And you can work at your own pace and when you're finished just let me know and then we have one little finish-up task to do and then that's it. So do you have any questions?
SUB: *And it's expected that we read every one of these?*
[Points to set of information sources]

The following interactions were found in IWI1.2, .3, and .4:

(13) 3.1.1.2.1:Session length:IN:A
(14) 1.2.2:Oral:IN:I
(15) 3.1.1.2.3:Resource availability:SY:C
(16) 3.2.1:Plan:MA:A

Interaction 13. The fourth IWI concerns an implied time limit. In this instance, the phrase "And you can work at your own pace . . ." is all the information given about time available for the session. It sets the *Session length* type in SKC.INFORMATION PROBLEM.TASK.CONSTRAINTS (3.1.1.2.1), albeit with no definite quantity.

Interaction 14. Two OPERATORs are evident in the problem solver's response to these incoming information types. One is the OPERATOR *Ingesting*, which includes the behavior of listening. Incoming information continues to be of the CLASS (1.2.2) type *Oral.* The intersection of *Oral* and *Ingesting* will remain marked with an I. This illustrates a convention that will be followed throughout the examples. Although *Ingesting* takes place constantly and could be shown as a TRANSFORMATION type *Changing* each succeeding time, the convention will be to indicate intersections of INFORMATION (1) types and the OPERATOR *Ingesting* as I, for *informing.* This seems to represent the actual state of affairs somewhat more clearly, since each new IWI instance involves a distinguishable intake of information.

Interaction 15. The second OPERATOR is *Synthesizing* (SY), which includes integrating information with previously developed knowledge. In response to the researcher's opportunity to ask questions, the subject asks "And it's expected that we read every one of these?" This response indicates the problem solver's attention during the delivery of the task instructions and also serves to clarify the problem solver's understanding of the *Resource availability* type of the RESOURCES aspect of CONSTRAINTS (3.1.1.2.3). Its intersection with OPERATOR *Synthesizing* is marked with the TRANSFORMATION type *Changing*, since the oral instructions provide information which elaborates on what had already been given.

There are several other interpretations of the effect of this information interaction. It is possible that the problem solver is trying to form a more determinate amount of time for the TIME (3.1.1.2.1) type *Session length.* The phrase "every one of these" implies a certain amount of time in virtue of how long it would take for this problem solver to read an information source set of the magnitude of this one. The problem solver is the best judge of the probable time required and may be making that judgment during this interaction.

Interaction 16. A second possibility is that this interaction gives some indication of the problem solver's initial *plan* of action, which is a type of WORLD KNOWLEDGE.PROBLEM SOLVING STRATEGY (3.2.1). Although the instructions do not request the participant to read the documents, they do include a remark about reading aloud (IWI1.3). The problem solver builds upon this remark and past experience to ask about reading documents. This implies a nascent plan in which reading plays some part. The OPERATOR (2.1) for this interaction would be *Managing*, which includes the behavior of strategizing.

The emerging grid is shown in Table 4.2.

IWI1.5 and IWI1.6

IWI1.5
RES: No. It's expected that you answer the question.
SUB: *Oh.*

Table 4.2.
Effects of IWI1.2, IWI1.3 and IWI1.4 on IWI Grid for Example One

BRANCH AND ASPECT	OPERATOR TYPE	CU	SE	AS	SI	IN	PU	AN	SY	MO	GR	MA
Info.Seed.Content (1.1.2)	*Individual topic*	o	o	o	o	o	o	o	o	o	o	o
Info.PhysSource.Class (1.2.2)	*Problem stmt*	o	o	o	o	o	o	o	o	o	o	o
	Set of Documents	o	o	o	o	o	o	o	o	o	o	o
	Oral	o	o	o	o	**I**	o	o	o	o	o	o
SKC.InfoPrb.Task.Cnstrt.Time (3.1.1.2.1)	*Session length*	o	o	o	o	**A**	o	o	o	o	o	o
SKC.InfoPrb.Task.Cnstrt.Answer	*Answer form*	o	o	o	o	o	o	o	o	o	o	o
(3.1.1.2.2)	*Answer length*	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Task.Cnstrt.Resources	*Resource avail*	o	o	o	o	o	o	o	**C**	o	o	o
(3.1.1.2.3)	*Personal property*	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Know.Topical (3.1.2.1)	*Developing*	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Situation (3.1.3)	*Materials*	o	o	o	o	o	o	o	o	o	o	o
	Place	o	o	o	o	o	o	o	o	o	o	o
	Time	o	o	o	o	o	o	o	o	o	o	o
SKC.WorldKnowl.PrbSolvingStrategy	*Plan*	o	o	o	o	o	o	o	o	o	o	**A**
(3.2.1)	*Progress*	o	o	o	o	o	o	o	o	o	o	o

A = *Adding*; C = *Changing*; I = *Informing*

IWI1.6
RES: I don't care how you do it. If you can do it from one document, do it that way. If you want to read every one, page by page, line by line, word by word, that's fine too. But the idea is that you're solving this problem. You have a need to understand the development of nonfiction for children as a literary art form and these are some sources that may or may not help you do that. Okay? And you can work at your own pace and do what you would normally do when you're solving this kind of problem.
SUB: *Okay.*

The following interactions were found in these IWI incidents:

(17) 3.1.1.2.3: Resource availability:IN:A
(18) 1.2.2:Oral:IN:I
(19) 3.1.1.2.3:Resource availability:SY:C

These two IWI are considered together. The mental connections of the problem solver are clearer when the IWI incidents are joined.

Interactions 17 and 18. The structure which is affected by these IWI instances is again RESOURCES (3.1.1.2.3), particularly the type *Resource Availability*. The oral instruction ". . . these are some sources that may or may not help you do that." indicates availability of documents, thus activating *Ingesting*. The participant's two verbalizations, Oh and Okay, are interpreted once again as signs of taking in the researcher's response. The intersection of *Oral* and the OPERATOR, *Ingesting*, is based on the fact that the oral information is obviously being listened to. This intersection is already marked with an I, thus no change will be noticeable in the grid entry.

Interaction 19. The OPERATOR *Synthesizing* brings about integration of the oral information with that previously stored; thus, the TRANSFORMATION type *Changing* becomes appropriate at its intersection with *Resource availability*. Since the intersection is already marked C, no difference in the grid entry will be evident.

After processing IWI1.5 and IWI1.6, which did engender activity but did not add or change entries in the grid, the grid for Example One appears as shown below in Table 4.3.

Table 4.3 also depicts the grid's composite condition at the end of the time period that Example One covered. It shows all the structures and operators that were active during the time involved, giving a bird's eye view of ongoing activity for the two minutes.

The IWI grid, however, does not attempt to portray one known activity of human memory. Information processed in working storage does not remain active forever. There are two alternatives for its eventual disposition, since it is highly likely that information being processed from IWI1.1 will not continue to reside in working memory during processing of succeeding IWI instances. One, the information

Table 4.3.
Composite IWI Grid for Example One including Effects of IWI1.5 and IWI1.6

BRANCH AND ASPECT	TYPE / OPERATOR	CU	SE	AS	SI	IN	PU	AN	SY	MO	GR	MA
Info.Seed.Form.LiteraryDevice (1.1.1.1)	*Metaphor*	O	O	O	O	O	O	O	O	O	O	O
	. . .	O	O	O	O	O	O	O	O	O	O	O
Info.Seed.Form.PhysFormat.Document	*Publisher*	O	O	O	O	O	O	O	O	O	O	O
(1.1.1.2.1)	. . .	O	O	O	O	O	O	O	O	O	O	O
Info.Seed.Form.PhysFormat.Linguistic	*Word*	O	O	O	O	O	O	O	O	O	O	O
(1.1.1.2.2)	. . .	O	O	O	O	O	O	O	O	O	O	O
Info.Seed.Content (1.1.2)	*Individual topic*	O	O	O	O	**I**	O	O	O	O	O	O
	To-date	O	O	O	O	O	O	O	O	O	O	O
Info.PhysSource.Imperfections (1.2.1)	*Truncated word*	O	O	O	O	O	O	O	O	O	O	O
Info.PhysSource.Class (1.2.2)	*Info source doc*	O	O	O	O	O	O	O	O	O	O	O
	Problem stmt	O	O	O	O	**I**	O	O	O	O	O	O
	Set of Documents	O	O	O	O	**I**	O	O	O	O	O	O
	Oral	O	O	O	O	**I**	O	O	O	O	O	O
SKC.InfoPrb.Task.Phy Product (3.1.1.1)	*Notes*	O	O	O	O	O	O	O	O	O	O	O
	Marks	O	O	O	O	O	O	O	O	O	O	O
	Answer	O	O	O	O	O	O	O	O	O	O	O
	Revised answer	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Task.Cnstrt.Time (3.1.1.2.1)	*Session length*	O	O	O	O	**A**	O	O	O	O	O	O
SKC.InfoPrb.Task.Cnstrt.Answer	*Answer form*	O	O	O	O	**A**	O	O	O	O	O	O
(3.1.1.2.2)	*Answer length*	O	O	O	O	**A**	O	O	O	O	O	O
SKC.InfoPrb.Task.Cnstrt.Resources	*Resource avail*	O	O	O	O	**A**	O	O	**C**	O	O	O
(3.1.1.2.3)	*Personal property*	O	O	O	O	**A**	O	O	O	O	O	O
SKC.InfoPrb.Know.Topical (3.1.2.1)	*Preexisting*	O	O	O	O	O	O	O	O	O	O	O
	Developing	O	O	O	O	**A**	O	O	O	O	O	O
SKC.InfoPrb.Know.WrkCns.Pertinence	*Info expression*	O	O	O	O	O	O	O	O	O	O	O
(3.1.2.2.1)	*Article*	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.WrkCns.Summary	*Summary*	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.WrkCns.InfoText	*Scope of article*	O	O	O	O	O	O	O	O	O	O	O
(3.1.2.2.3)	*Clarity of expr*	O	O	O	O	O	O	O	O	O	O	O
	Validity of expr	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.WrkCns.Expectations	*Expectations*	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Situation (3.1.3)	*Materials*	O	O	O	O	**A**	O	O	O	O	O	O
	Place	O	O	O	O	**I**	O	O	O	O	O	O
	Time	O	O	O	O	**I**	O	O	O	O	O	O
SKC.WorldKnowl.PrbSolvingStrategy	*Plan*	O	O	O	O	O	O	O	O	O	O	**A**
(3.2.1)	*Progress*	O	O	O	O	O	O	O	O	O	O	O
	Goal	O	O	O	O	O	O	O	O	O	O	O
	Time	O	O	O	O	O	O	O	O	O	O	O
SKC.WorldKnowledge.Self-knowledge	*Cognitive style*	O	O	O	O	O	O	O	O	O	O	O
(3.2.2)	*Grammar*	O	O	O	O	O	O	O	O	O	O	O

A = *Adding*; C = *Changing*; I = *Informing*

goes away, leaving no trace of its processing; and two, the information becomes part of the participant's long term knowledge base.

It is incontrovertible that humans do not remember everything that passes through their working memory. Unfortunately, at this time, not enough is known about the creation of memory to give a principled method for distinguishing between which incoming pieces of information will or will not stored. Given this state of affairs, it becomes a modeler's choice whether to continue to display the item as active in the grid. This model will not depict fading or non-transference to long term memory. In the service of presenting a composite of interactions, once processed, information will be considered to be available as stored memory.

Example Two - Beginning the Task

The second example considers three minutes in which one participant begins problem solving (a5.1156.12). This example has 8 IWI incidents and 35 interactions. It begins immediately after the subject's response to the researcher's request to state the information need and continues until the participant begins reading the first source. The major activity is becoming acquainted with the set of information sources.

Because this example relies heavily upon participant actions, actions will be displayed on separate lines of text in brackets to facilitate location and recognition. To aid the tracking of each document, they will be referred to by their color in the statements about action.

Of the five subsets of documents that were created during this three minutes, three remained at the end. The subsets and their sorting bases are described below. Set.1: gray, buff, salmon and pink together, in that order from the top, held in participant's hand, basis unstated but inferred to be not-tools; Set.4: blue, eliminated from further consideration because evaluation determined topic to be a secondary factor; and Set.5: goldenrod and green, planned to be read second and third, placed together with slight overlap on the possible basis that their foci were tools. Intermediate Set.2 and Set.3 were formed and dissolved during processing. From Set.1, the gray document was chosen for reading on the basis of being the shortest in its subset.

IWI2.1

RES: Go ahead and start.
SUB: *Okay. Let me see.*
[Picks up set; looks at pink]
Software tools for indexing, what we need, *title.*
[Sets aside pink]

The interactions found in this IWI incident are shown here:

(20) 1.1.1.2.1:Title:IN:I
(21) 1.2.2:Set of documents:IN:I
(22) 1.2.2:Set.1:GR:A

Interactions 20 and 21. The first actions of the problem solver are to pick up the set of documents, read the title of the top document and put it by itself. These actions indicate the use of INFORMATION (1) structures DOCUMENT (1.1.1.2.1) and CLASS (1.2.2). *Title* intersects with the OPERATOR *Ingesting* with TRANSFORMATION code I, indicating that the problem solver was using the source title as information. *Set of documents* intersected with OPERATOR *Ingesting* also, with the TRANSFORMATION code I, to show that the set was being taken in as a group.

Interaction 22. This IWI incident also shows the initiation of a subset within *Set of documents*. Through the OPERATOR *Grouping*, specifically the behavior sorting, *Set of documents* is separated into two groups. No basis is given verbally for the separation; the action seems to indicate that the problem solver was merely disposing of a document in order to go on to the next one in the set. However, the result is to produce two groups of documents, so the first subset is considered to be created. It is labeled Set.1 and contains one document, Pink.

At this time the entries in Table 4.4 have been created for the IWI grid.

Table 4.4.
Effects of IWI2.1 on IWI Grid for Example Two

	OPERATOR	C	S	A	S	I	P	A	S	M	G	M
BRANCH AND ASPECT (BAS NBR)	TYPE	U	E	S	I	N	U	N	Y	O	R	A
Info.Seed.Form.PhysFormat.Document	*Publisher*	O	O	O	O	O	O	O	O	O	O	O
(1.1.1.2.1)	*Title*	O	O	O	O	**I**	O	O	O	O	O	O
Info.PhysSource.Class (1.2.2)	*Set of Documents*	O	O	O	O	**I**	O	O	O	O	O	O
	Set.1	O	O	O	O	O	O	O	O	O	**A**	O
A = *Adding*; C = *Changing*; I = *Informing*												

IWI2.2

Index-It, low cost indexing, *title.*
[Looks at blue; sets blue with pink]

The interactions found in this IWI follow:

(23) 1.1.1.2.1:Title:IN:I
(24) 1.2.2:Set.1:GR:C

Interactions 23 and 24. This IWI incident continues with the reading of a second title, and the changing of Set.1 by adding an element. INFORMATION aspect DOCUMENT (1.1.1.2.1) is active, using *Title* as information for *Ingesting*. *Grouping* is also an active OPERATOR with Set.1 which is part of *Set of Documents* under CLASS (1.2.2). The result is to change Set.1 by adding one element, Blue, with no indication of the basis for doing so. At the end of this IWI instance, the new grid entries included the TRANSFORMATION code, C, at the intersection of Set.1 and *Grouping*.

Table 4.5 shows the effects from this IWI.

Table 4.5.
Effects of IWI2.2 on IWI Grid for Example Two

BRANCH AND ASPECT (BAS NBR)	TYPE	OPERATOR CU	SE	AS	SI	IN	PU	AN	SY	MO	GR	MA
Info.Seed.Form.PhysFormat.Document	*Publisher*	O	O	O	O	O	O	O	O	O	O	O
(1.1.1.2.1)	*Title*	O	O	O	O	I	O	O	O	O	O	O
Info.PhysSource.Class (1.2.2)	*Set of Documents*	O	O	O	O	O	O	O	O	O	O	O
	Set.1	O	O	O	O	O	O	O	O	O	C	O
A = *Adding*; C = *Changing*; I = *Informing*												

<u>IWI2.3</u>

> [Looks at buff]
> Index-Aid, computer-assisted back of the book. Index Aid, low cost, tools, money, aid. Tools, *I'll put -- possibly tools together.*
> [Looks at blue and pink; sets buff apart from pile of blue and pink]
> [Interruption for technical check of equipment]

The interactions found in IWI2.3 are shown below:

(25) 1.1.1.2.1:Title:IN:I
(26) 1.2.2:Set.2:GR:A
(27) 3.2.1:Goal:GR:A
(28) 1.1.2:To-date:SY:A
(29) 3.2.1:Plan:MA:A
(30) 3.1.2.1:Developing:MA:A

<u>Interaction 25</u>. IWI2.3 includes the first indication of the basis for sorting, as the problem solver continues to read the titles of the individual sources. This is the familiar interaction of DOCUMENT type *Title* with OPERATOR *Ingesting.*

<u>Interactions 26 and 27</u>. The words "I'll put -- possibly tools together." with the subsequent action of putting a new document to one side

indicates a number of things. First, it shows that the problem solver is beginning to establish a basis for a group. Through the interaction of *Set of Documents* and *Grouping*, a new subset, Set.2, is created. This is reflected in the intersection as A. There is also an interaction with *Goal*, under PROBLEM SOLVING STRATEGY (3.2.1). *Grouping* is being implemented in the behavior sorting; sorting now involves a basis that has been indicated. Thus, the purpose of the sort is also indicated and is recorded as the TRANSFORMATION, *adding*, for the type *Goal*.

Interaction 28. The response of the problem solver also shows that the problem solver is comparing two things, in this case the problem solver's conception of the foci of sources as indicated by their titles. This behavior activates the OPERATOR *Synthesizing*. Since the objects of the comparison are the three source titles read so far, INFORMATION structure *To-date* (1.1.2) seems appropriate as the activating information. This is a new result, thus the TRANSFORMATION is *adding*.

Interactions 29 and 30. Another result of this IWI incident is to show the beginning of knowledge about a *Plan* for selecting topical knowledge that responds to the knowledge need. Here, two different SOLVER'S KNOWLEDGE COMPONENT structures are active: *Plan* under PROBLEM SOLVING STRATEGY (3.2.1) to show that knowledge of a plan is developing; and *Developing* under TOPICAL (3.1.2.1) to show that the topical knowledge is beginning to be gathered. The OPERATOR for both structures is *Managing*, specifically strategizing. Both intersections are marked A for the TRANSFORMATION type, since this appears to be the first time they are attended to by the problem solver.

At the conclusion of this IWI, the grid entries were as shown in Table 4.6.

Table 4.6.
Effects of IWI2.3 on IWI Grid for Example Two

BRANCH AND ASPECT (BAS NBR)	OPERATOR TYPE	C U	S E	A S	S I	I N	P U	A N	S Y	M O	G R	M A
Info.Seed.Form.PhysFormat.Document	*Publisher*	O	O	O	O	O	O	O	O	O	O	O
(1.1.1.2.1)	*Title*	O	O	O	O	**I**	O	O	O	O	O	O
Info.Seed.Content (1.1.2)	*Individual topic*	O	O	O	O	C	O	O	O	O	O	O
	To-date	O	O	O	O	O	O	O	**A**	O	O	O
Info.PhysSource.Class (1.2.2)	*Set of Documents*	O	O	O	O	O	O	O	O	O	O	O
	Set.1	O	O	O	O	O	O	O	O	O	O	O
	Set.2	O	O	O	O	O	O	O	O	O	**A**	O
SKC.InfoPrb.Know.Topical (3.1.2.1)	*Preexisting*	O	O	O	O	O	O	O	O	O	O	O
	Developing	O	O	O	O	O	O	O	O	O	O	**A**
SKC.WorldKnowl.PrbSolvingStrategy	*Plan*	O	O	O	O	O	O	O	O	O	O	**A**
(3.2.1)	*Progress*	O	O	O	O	O	O	O	O	O	O	O
	Goal	O	O	O	O	O	O	O	O	O	**A**	O

A = *Adding*; C = *Changing*; I = *Informing*

<u>IWI2.4 and IWI2.5</u>

IWI2.4
[Looks at blue; looks at goldenrod]
Indexing.
[inaudible] *title*

IWI2.5
Indexing, product is Macrex. Macrex.
[Sets goldenrod with blue; looks at green]
And What's Ahead for Indexing Software.
[Sets green by itself; looks at salmon]
Getting Started in Computerized Indexing.
[Picks up goldenrod; put with salmon]
Tools, indexing, getting started. *Let's see.*
[Picks up goldenrod; sets salmon with blue; separates blue; picks up buff]
Index Aid. *Put these together.*
[Sets buff with salmon]

The interactions found for these IWI incidents are shown below:

(31) 1.1.1.2.1:Title:IN:I
(32) 1.1.1.2.1:Title:IN:I
(33) 1.2.2:Set.1:GR:C
(34) 1.2.2:Set.4:GR:A

(35) 1.2.2:Set.5:GR:A
(36) 1.2.2:Set.2:GR:C
(37) 1.2.2:Set.1:GR:C
(38) 3.2.1:Goal:GR:C
(39) 3.1.2.1:Developing:SY:C
(40) 1.2.2:Set.3:GR:A

Interaction 31. These two IWI instance are treated together. IWI2.4 consisted of the continued reading of *Titles* by the OPERATOR *Ingesting*. As such, it does not change the appearance of the grid.

Interaction 32. IWI2.5 continues to take in new titles, giving rise to the intersection of *Ingesting* and *Title*, with TRANSFORMATION code I.

Interactions 33 and 34. Looking at the changes to Set.1 first, the action "[Sets goldenrod with blue; . . .]" added a new member; this affected *Set of documents*, specifically Set.1, a type under CLASS (1.2.2) by using the OPERATOR *Grouping*, and is recorded at the intersection as using TRANSFORMATION type C.

Set.1 also loses a member, Blue, from its set. The action "[. . .; separates blue; . . .]" indicates both the modification of Set.1 and the creation of Set.4. The creation of Set.4 is shown as the intersection of *Grouping* and Set.4 with TRANSFORMATION type A. Set.4 contains one member, Blue. Set.1 is already marked as changed.

Interaction 35. Set.5 is also created when one document, Goldenrod, is moved from Set.1 to a set of its own. The creation of Set.5 follows the same sequence as for Set.4.

Interactions 36 and 37. Later in the interaction, Set.1 and Set.2 (elements of CLASS (1.2.2)) are modified by moving a document from one to the other. The problem solver's response "Put these together." is followed by the action of "[Sets buff on salmon]." Moving Buff, which was the sole member of Set.2, causes the entire subset to disappear. This disappearance is reflected in the intersection of Set.2 and *Grouping*, with a TRANSFORMATION of C. Set.1 acquired a new member (Buff) from this move. These two actions are reflected in the intersection of Set.1 and *Grouping*, again with TRANSFORMATION type C.

Interactions 38 and 39. Also changed by this rearrangement of Blue was *Goal*, a part of PROBLEM SOLVING STRATEGY (3.2.1) by the choice of a new grouping, shown as TRANSFORMATION C under *Grouping*. *Developing*, a type under TOPICAL (3.1.2.1), was revised through the OPERATOR *Synthesizing*, specifically through the behaviors of comparing and integrating.

Interaction 40. The action "[Sets green by itself; . . .]" indicates the creation of a another subset, Set.3. Again, the type *Set of Documents* under CLASS (1.2.2) is affected by the OPERATOR *Grouping*, with the TRANSFORMATION type A recorded for Set.3.

At the conclusion of these two IWI instances, the grid, as shown in Table 4.7, has been modified by the entries shown.

IWI2.6

> [Looks at gray]
> Index Maker, Automatic Indexing from Word-Processor Text. Automatic Indexing from Word-Processor Text, *okay. These two.*
> [Sets gray with buff]

Interactions found in IWI2.6 are shown below:

(41) 1.1.1.2.1:Title:IN:I
(42) 1.2.2:Set.1:GR:C
(43) 3.2.1:Goal:GR:C
(44) 3.1.2.1:Developing:SY:C

Table 4.7.
Effects of IWI2.4 and IWI2.5 on IWI Grid for Example Two

	OPERATOR	C	S	A	S	I	P	A	S	M	G	M
BRANCH AND ASPECT (BAS NBR)	TYPE	U	E	S	I	N	U	N	Y	O	R	A
Info.Seed.Form.PhysFormat.Document	*Publisher*	O	O	O	O	O	O	O	O	O	O	O
(1.1.1.2.1)	*Title*	O	O	O	O	**I**	O	O	O	O	O	O
Info.Seed.Content (1.1.2)	*Individual topic*	O	O	O	O	O	O	O	O	O	O	O
	To-date	O	O	O	O	O	O	O	O	O	O	O
Info.PhysSource.Class (1.2.2)	*Set of Documents*	O	O	O	O	O	O	O	O	O	O	O
	Set.1	O	O	O	O	O	O	O	O	O	**C**	O
	Set.2	O	O	O	O	O	O	O	O	O	**C**	O
	Set.3	O	O	O	O	O	O	O	O	O	**A**	O
	Set.4	O	O	O	O	O	O	O	O	O	**A**	O
	Set.5	O	O	O	O	O	O	O	O	O	**A**	O
SKC.InfoPrb.Know.Topical (3.1.2.1)	*Preexisting*	O	O	O	O	O	O	O	O	O	O	O
	Developing	O	O	O	O	O	O	O	**C**	O	O	O
SKC.WorldKnowl.PrbSolvingStrategy	*Plan*	O	O	O	O	O	O	O	O	O	O	O
(3.2.1)	*Goal*	O	O	O	O	O	O	O	O	O	**C**	O
A = *Adding*; C = *Changing*; I = *Informing*												

Interactions 41, 42, 43, and 44. In these interactions, the problem solver continues using *Title* (1.1.1.2.1) as information, supporting the *Ingesting* OPERATOR. Another document (Gray) not previously assigned to any set is added to Set.1, evidenced by both the verbal remark "Okay. These two." and the action "[Set gray with buff]". Again, not only are the physical arrangements of the documents affected, but also the mental structures *Goal* and *Developing*. *Goal* is once again changed by *Grouping*; *Developing* by *Synthesizing*. In both cases, the TRANSFORMATION type is C.

At the end of this IWI, the grid has been modified with the entries in Table 4.8.

Table 4.8.
Effects of IWI2.6 on IWI Grid for Example Two

BRANCH AND ASPECT (BAS NBR)	OPERATOR TYPE	CU	SE	AS	SI	IN	PU	AN	SY	MO	GR	MA
Info.Seed.Form.PhysFormat.Document	*Publisher*	O	O	O	O	O	O	O	O	O	O	O
(1.1.1.2.1)	*Title*	O	O	O	O	I	O	O	O	O	O	O
Info.PhysSource.Class (1.2.2)	*Set of Documents*	O	O	O	O	O	O	O	O	O	O	O
	Set.1	O	O	O	O	O	O	O	O	O	C	O
	Set.2	O	O	O	O	O	O	O	O	O	O	O
	Set.3	O	O	O	O	O	O	O	O	O	O	O
	Set.4	O	O	O	O	O	O	O	O	O	O	O
	Set.5	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.Topical (3.1.2.1)	*Preexisting*	O	O	O	O	O	O	O	O	O	O	O
	Developing	O	O	O	O	O	O	O	C	O	O	O
SKC.WorldKnowl.PrbSolvingStrategy	*Plan*	O	O	O	O	O	O	O	O	O	O	O
(3.2.1)	*Goal*	O	O	O	O	O	O	O	O	O	C	O

A = *Adding*; C = *Changing*; I = *Informing*

IWI2.7

> [Picks up green, picks up blue]
> Macrex, low cost. Software capabilities. Capabilities *for indexing. I will not read Index low cost simply because I don't see it as a capability for software creation. It would be a factor, but a secondary factor after determining*
> [Picks up goldenrod]
> *what the software -- the program should look like.*
> [Sets blue in separate pile]

The interactions for this IWI incident are shown below:

(45) 1.2.2:Set.4:CU:C
(46) 3.2.1:Plan:MA:C
(47) 3.1.2.2.1:Article:AN:A
(48) 3.1.2.1:Developing:CU:C

Interactions 45 and 46. Here is an interaction (45) that eliminates one document based on an evaluation of its topic and a prediction of the topic's value to the development of the answer. The action "[Sets blue in separate pile]" plus the verbal report "I will not read Index low cost . . ." affect Set.4 under CLASS (1.2.2) by the OPERATOR *Culling. Culling,* manifested in both behaviors eliminating and setting aside, effectively removes the document and set from further use or consideration. A related interaction (46) is available in this IWI incident. The remark "I will not read Index low cost . . ." indicates that a *Plan* is being developed by the problem solver. This type, part of PROBLEM SOLVING STRATEGY (3.2.1), intersects with *Managing*, the OPERATOR which includes strategizing as a behavior. This is not the first mention of a plan, thus the TRANSFORMATION type is C.

Interaction 47. Also affected by the statement ". . .because I don't see it as a capability for software creation." is *Article*, a type under PERTINENCE (3.1.2.2.1). The appropriate OPERATOR is *Anticipating*, which shows the problem solver predicting the value of the document for the answer. The intersection reflects TRANSFORMATION type A since no overt mention of pertinence for this article has been shown previously.

Interaction 48. Also affected by the elimination of Blue is the type *Developing*, under TOPICAL. The relegation of a topical unit as not particularly pertinent is evidence that the topical knowledge of the knowledge need is growing, since the elimination is explained. Thus, the intersection of *Culling* and *Developing* indicates this interaction would be TRANSFORMATION type C, since this structure has been activated previously. These entries are shown in Table 4.9 below.

IWI2.8

[Looks at green]
Macrex *sounds like -- let's see, IBM.*
[Replaces goldenrod in same location by itself]
Well, I'll read this second, and
[Sets green with goldenrod]
what's ahead possibly third. So I first organized my papers,
[Picks up buff, salmon, gray, pink]
taking Index Maker, Automatic Indexing from Word-Processor Text, Index Aid Computer-Assisted Back-of-the-Book Indexing, Getting Started in Computerized Indexing, Software Tools for Indexing.

[Chooses gray; places on top of buff]
I'm going with Index Maker first, simply because it's the shortest.

Table 4.9.
Effects of IWI2.7 on IWI Grid for Example Two

BRANCH AND ASPECT (BAS NBR)	OPERATOR TYPE	C U	S E	A S	S I	I N	P U	A N	S Y	M O	G R	M A
Info.PhysSource.Class (1.2.2)	*Set of Documents*	O	O	O	O	O	O	O	O	O	O	O
	Set.1	O	O	O	O	O	O	O	O	O	O	O
	Set.2	O	O	O	O	O	O	O	O	O	O	O
	Set.3	O	O	O	O	O	O	O	O	O	O	O
	Set.4	**C**	O	O	O	O	O	O	O	O	O	O
	Set.5	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.Topical (3.1.2.1)	*Preexisting*	O	O	O	O	O	O	O	O	O	O	O
	Developing	**C**	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.WrkCns.Pertinence (3.1.2.2.1)	*Info expression*	O	O	O	O	O	O	O	O	O	O	O
	Article	O	O	O	O	O	O	**A**	O	O	O	O
SKC.WorldKnowl.PrbSolvingStrategy (3.2.1)	*Plan*	O	O	O	O	O	O	O	O	O	O	**C**
	Goal	O	O	O	O	O	O	O	O	O	O	O

A = *Adding*; C = *Changing*; I = *Informing*

Interactions that are found in this IWI incident are shown below:

(49) 1.2.2:Set.3:GR:C
(50) 1.2.2:Set.5:GR:C
(51) 3.2.1:Plan:MA:C
(52) 3.2.1:Progress:MA:A
(53) 1.2.2:Set.1:IN:I
(54) 1.2.2:Information source document:SE:A

Interactions 49, 50 and 51. The first effect is to eliminate a set by combining two. Green, the only member of Set.3, is placed with Goldenrod, to increase Set.5 to a membership of two. This is accomplished by the OPERATOR *Grouping*, with input from Set.3 and Set.5, types under CLASS (1.2.2). The intersection reflects a TRANSFORMATION type of C for both sets. At the same time, the remark "Well, I'll read this second [goldenrod] and what's ahead possibly third. [green]" indicates a *Plan*, the result of behavior strategizing under OPERATOR *Managing*. Since a *Plan* has been developed earlier in this example, the TRANSFORMATION code is C.

Interactions 52 and 53. Next, the problem solver picks up Set.1 and reads the titles of each of the members. Active here is the *Managing* OPERATOR again, this time with the type *Progress* under PROBLEM SOLVING STRATEGY (3.2.1). The problem solver's remark "So I first organized my papers, . . . " shows that there is a reviewing of activities accomplished so far in the session. Also, Set.1 is serving as input, using the OPERATOR *Ingesting*, with I as TRANSFORMATION type.

Interaction 54. The final action is to choose a single document to pursue. Gray is chosen through the OPERATOR *Selecting*, specifically by behavior choosing. The intersection reflects *adding* as the TRANSFORMATION, since this the first time a document has been chosen for reading. Even though this is a single document, since it is the only one being referred to, it is not necessary to distinguish it further than as *Information source document*. Table 4.10 shows the interactions from this IWI incident.

Table 4.10.
Effects of IWI2.8 on IWI Grid for Example Two

	OPERATOR	C	S	A	S	I	P	A	S	M	G	M
BRANCH AND ASPECT (BAS NBR)	TYPE	U	E	S	I	N	U	N	Y	O	R	A
Info.PhysSource.Class (1.2.2)	*Info source doc*	O	A	O	O	O	O	O	O	O	O	O
	Set of documents	O	O	O	O	O	O	O	O	O	O	O
	Set.1	O	O	O	O	I	O	O	O	O	O	O
	Set.2	O	O	O	O	O	O	O	O	O	O	O
	Set.3	O	O	O	O	O	O	O	O	O	C	O
	Set.4	O	O	O	O	O	O	O	O	O	O	O
	Set.5	O	O	O	O	O	O	O	O	O	C	O
SKC.WorldKnowl.PrbSolvingStrategy	*Plan*	O	O	O	O	O	O	O	O	O	O	C
(3.2.1)	*Progress*	O	O	O	O	O	O	O	O	O	O	A
	Goal	O	O	O	O	O	O	O	O	O	O	O

A = *Adding*; C = *Changing*; I = *Informing*

The composite IWI grid for Example Two appears in Table 4.11 to recap the interactions that occurred.

Table 4.11.
Composite IWI Grid for Example Two - Beginning the Task

BRANCH AND ASPECT (BAS NBR)	OPERATOR TYPE	C U	S E	A S	S I	I N	P U	A N	S Y	M O	G R	M A
Info.Seed.Form.Literary Device (1.1.1.1)	*Metaphor*	o	o	o	o	o	o	o	o	o	o	o
	. . .	o	o	o	o	o	o	o	o	o	o	o
Info.Seed.Form.PhysFormat.Document	*Publisher*	o	o	o	o	o	o	o	o	o	o	o
(1.1.1.2.1)	*Publication date*	o	o	o	o	o	o	o	o	o	o	o
	Title	o	o	o	o	**I**	o	o	o	o	o	o
	. . .	o	o	o	o	o	o	o	o	o	o	o
Info.Seed.Form.PhysFormat.Linguistic	*Word*	o	o	o	o	o	o	o	o	o	o	o
(1.1.1.2.2)	*Phrase*	o	o	o	o	o	o	o	o	o	o	o
	. . .	o	o	o	o	o	o	o	o	o	o	o
Info.Seed.Content (1.1.2)	*Individual topic*	o	o	o	o	o	o	o	o	o	o	o
	To-date	o	o	o	o	o	o	o	**A**	o	o	o
Info.PhysSource.Imperfections (1.2.1)	*Truncated word*	o	o	o	o	o	o	o	o	o	o	o
Info.PhysSource.Class (1.2.2)	*Info source doc*	o	**A**	o	o	o	o	o	o	o	o	o
	Problem Stmt	o	o	o	o	o	o	o	o	o	o	o
	Set of documents	o	o	o	o	**I**	o	o	o	o	o	o
	Set.1	o	o	o	o	**I**	o	o	o	o	**C**	o
	Set.2	o	o	o	o	o	o	o	o	o	**C**	o
	Set.3	o	o	o	o	o	o	o	o	o	**C**	o
	Set.4	**C**	o	o	o	o	o	o	o	o	**A**	o
	Set.5	o	o	o	o	o	o	o	o	o	**C**	o
	Oral	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Task.Phy Product (3.1.1.1)	*Notes*	o	o	o	o	o	o	o	o	o	o	o
	. . .	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Task.Cnstrt.Time (3.1.1.2.1)	*Session length*	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Task.Cnstrt.Answer	*Answer form*	o	o	o	o	o	o	o	o	o	o	o
(3.1.1.2.2)	*Answer length*	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Task.Cnstrt.Resources	*Resource avail*	o	o	o	o	o	o	o	o	o	o	o
(3.1.1.2.3)	*Personal Property*	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Know.Topical (3.1.2.1)	*Preexisting*	o	o	o	o	o	o	o	o	o	o	o
	Developing	**C**	o	o	o	o	o	o	**C**	o	o	**A**
SKC.InfoPrb.Know.WrkCns.Pertinence	*Info expression*	o	o	o	o	o	o	o	o	o	o	o
(3.1.2.2.1)	*Article*	o	o	o	o	o	o	**A**	o	o	o	o
SKC.InfoPrb.Know.WrkCns.Summaries	*Summary*	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Know.WrkCns.InfoText	*Scope of article*	o	o	o	o	o	o	o	o	o	o	o
(3.1.2.2.3)	*Clarity of expr*	o	o	o	o	o	o	o	o	o	o	o
	Validity of expr	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Know.WrkCns.Expectations	*Expectations*	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Situation	*Materials*	o	o	o	o	o	o	o	o	o	o	o
(3.1.3)	*Place*	o	o	o	o	o	o	o	o	o	o	o
	Time	o	o	o	o	o	o	o	o	o	o	o
SKC.WorldKnowl.PrbSolvingStrategy	*Plan*	o	o	o	o	o	o	o	o	o	o	**C**
(3.2.1)	*Progress*	o	o	o	o	o	o	o	o	o	o	**A**
	Goal	o	o	o	o	o	o	o	o	o	**C**	o
	Time	o	o	o	o	o	o	o	o	o	o	o
SKC.WorldKnowledge.Self-knowledge	*Cognitve style*	o	o	o	o	o	o	o	o	o	o	o
(3.2.2)	*Grammar*	o	o	o	o	o	o	o	o	o	o	o

A = *Adding*; C = *Changing*; I = *Informing*

Example Two demonstrates that actions are very important when trying to understand problem solving in situations using physical artifacts. The verbal reports without a visual record of the actions to refer to would be almost indecipherable. Even with them, it was extremely difficult to describe the sorting and shuffling of sources that were going on, particularly when it was desired to indicate the underlying mental activity as well. Yet, it seems necessary to consider actions in order to recognize problem solving knowledge construction. As evidence of the mental action of grouping like with like, and eliminating the unlike, actions are invaluable. One is still obliged to use a large element of inferring; however, the visible evidence of a group in physical proximity to each other adds convincing corroboration to the inference.

Example Three - Using an Information Source

Example Three is a three minute selection as one problem solver used one of the written information sources (c17.1419.7). It consists of 7 IWI incidents and 26 interactions. This selection exemplifies the most common type of IWI incident that is found in the reports of the participants. As seems reasonable, absorbing information and forging knowledge consumed the majority of time and effort of problem solving.

This participant marks the documents by underlining. In order to show what is being picked out, the phrase or clause will be underlined here also, in addition to the action notation.

IWI3.1

> "[Picks up new document] Publisher's perspective. *This one is talking about* juvenile nonfiction books, the shift and how they're conceived, written and published for -- *this thing is right on target.*

The interactions found in this IWI incident are shown below:

(55) 1.1.1.2.1:Title:IN:I
(56) 1.1.1.2.2:Sentence:IN:I
(57) 3.1.2.2.1:Article:AN:A
(58) 3.1.2.2.1:Article:SY:C
(59) 3.1.2.1:Developing:SY:A

Interactions 55 and 56. This IWI incident begins processing of a new document. The first interaction is to read the title and most of the first sentence. In this instance, *Title*, a type of DOCUMENT (1.1.1.2.1) in the branch INFORMATION, is used by the OPERATOR (2.1) *Ingesting* for Information. Also active would be type *Sentence* from LINGUISTIC (1.1.1.2.2), again with the OPERATOR *Ingesting*, and coded I.

Interactions 57 and 58. The second response, ". . . this thing is right on target." indicates that the problem solver is comparing two items. The word 'this' identifies that one element of the comparison is the article itself; the word 'target' identifies the second element as a conception of the topic held by the participant. The entire sentence indicates that pertinence is being predicted. This analysis leads to several entries in the IWI grid. First, *Article*, a type under PERTINENCE (3.1.2.2.1), is acted upon by OPERATOR (2.1) *Anticipating*, with the TRANSFORMATION type A. In particular, the problem solver is predicting the value of the source for solving the problem, and has concluded that it is pertinent. At the same time, the problem solver is comparing *Article* to the conception of the knowledge gap that is held. Thus, the OPERATOR *Synthesizing*, which includes the behavior comparing is active, with a TRANSFORMATION effect of *changing*.

Interaction 59. In addition to *Article*, another structure within the SOLVER'S KNOWLEDGE COMPONENT is affected. That is *Developing*, a type under TOPICAL (3.1.2.1) which holds the topical knowledge that is composed during the session. It is also being added by the OPERATOR *Synthesizing.*

At the completion of IWI3.1, the grid contains these entries.

Table 4.12.
Effect of IWI3.1 on IWI Grid for Example Three

BRANCH AND ASPECT (BAS NBR)	OPERATOR TYPE	C U	S E	A S	S I	I N	P U	A N	S Y	M O	G R	M A
Info.Seed.Form.PhysFormat.Document	*Title*	0	0	0	0	**I**	0	0	0	0	0	0
(1.1.1.2.1)	. . .											
Info.Seed.Form.PhysFormat.Linguistic	*Word*	0	0	0	0	0	0	0	0	0	0	0
(1.1.1.2.2)	*Phrase*	0	0	0	0	0	0	0	0	0	0	0
	Sentence	0	0	0	0	**I**	0	0	0	0	0	0
	. . .	0	0	0	0	0	0	0	0	0	0	0
SKC.InfoPrb.Know.Topical (3.1.2.1)	*Preexisting*	0	0	0	0	0	0	0	0	0	0	0
	Developing	0	0	0	0	0	0	0	**A**	0	0	0
SKC.InfoPrb.Know.WrkCns.Pertinence	*Info expression*	0	0	0	0	0	0	0	0	0	0	0
(3.1.2.2.1)	*Article*	0	0	0	0	0	0	**A**	**C**	0	0	0

A = *Adding*; C = *Changing*; I = *Informing*

IWI3.2

> It's talking about a 1974 book about Juvenile Justice and -- *let's see if it's using it as a good or a bad example. I don't know yet.*[Silent reading] *It has some good things, but* no illustrations. *It's got* excellent reviews. *Had awards.*

The interactions found in this IWI are shown below:

(60) 1.1.1.2.2:Sentence:IN:I
(61) 1.1.1.1:Example:IN:I
(62) 3.2.1:Goal:PU:A
(63) 3.1.2.2.4:Expectations:AN:A
(64) 3.1.2.2.2:Summary:SY:A

Interactions 60 and 61. The interactions in this IWI instance begin with the OPERATOR *Ingesting* acquiring information in the form of *Sentence*, a type under LINGUISTIC (1.1.1.2.2). In fact, more than one sentence is involved in the information intake. At the same time, LITERARY DEVICE (1.1.1.1), specifically that of *Example*, is also active for the OPERATOR *Ingesting.*

Interaction 62. The participant's sentence "Let's see if it's using it as a good example or a bad example." demonstrates several different behaviors. In order to recognize them, the references of the two occurrences of 'it' in the sentence need to be resolved. In the first instance, the reference appears to be the author or the article being read; in the second, the reference seems to be to an example that is being presented in the text. Based on this analysis, the *Pursuing* OPERATOR, in the form of the behavior seeking, is recognized. The remark by the problem solver becomes "Let's see if [the author] is using [the example] as a good . . . " and indicates an active search for the author's use of the example presented. This behavior's existence is further supported by the remark "I don't know yet." with the word yet being interpreted as meaning not now but perhaps in the future. This creates an entry in the grid at the intersection of *Pursuing* and *Goal*, which is a type of PROBLEM SOLVING STRATEGY (3.2.1).

Interaction 63. In addition, this remark also shows an expectation of the purpose of the example. It may be either ". . . as a good or a bad example." This demonstrates the behavior forecasting, which is part of OPERATOR *Anticipating* and creates an entry at the intersection of *Anticipating* and *Expectations*, which is a type under WORKING CONSTRUCTIONS (3.1.2.2.4).

Interaction 64. The next interaction is that of summarizing a few pieces of information contained in the sentences following the one reported as read. The combination of silent reading visible on the video tape and the presence of a summarizing statement in the verbal report show that the problem solver did access information during the silent portion. The clause "It has some good things, . . ." is the remark that indicates a summary has been made. Again, the use of 'it' refers to something in the mind of the participant and needs resolution. In this instance, it refers to the example that is being presented in the text. The interpretation of the remark takes into account that the problem solver is trying to characterize the content of the sentences without going into detail. The result of the behavior summarizing is reflected in the grid intersection for *Summary*, a type under the aspect SUMMARY (3.1.2.2.2) and the OPERATOR *Synthesizing* as an A, for TRANSFORMATION.

Table 4.13 depicts the grid entries from this IWI incident.

Table 4.13.
Effect of IWI3.2 on IWI Grid for Example Three

BRANCH AND ASPECT (BAS NBR)	OPERATOR TYPE	CU	SE	AS	SI	IN	PU	AN	SY	MO	GR	MA
Info.Seed.Form.Literary Device (1.1.1.1)	*Metaphor*	O	O	O	O	O	O	O	O	O	O	O
	Analogy	O	O	O	O	O	O	O	O	O	O	O
	Example	O	O	O	O	**I**	O	O	O	O	O	O
Info.Seed.Form.PhysFormat.Linguistic	*Word*	O	O	O	O	O	O	O	O	O	O	O
(1.1.1.2.2)	*Phrase*	O	O	O	O	O	O	O	O	O	O	O
	Sentence	O	O	O	O	**I**	O	O	O	O	O	O
SKC.InfoPrb.Know.WrkCns.Pertinence	*Info expression*	O	O	O	O	O	O	O	O	O	O	O
(3.1.2.2.1)	*Article*	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.WrkCns.Summary	*Summary*	O	O	O	O	O	O	O	**A**	O	O	O
SKC.InfoPrb.Know.WrkCns.InfoText	*Scope of article*	O	O	O	O	O	O	O	O	O	O	O
(3.1.2.2.3)	*Clarity of expr*	O	O	O	O	O	O	O	O	O	O	O
	Validity of expr	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.WrkCns.Expectations	*Expectations*	O	O	O	O	O	O	**A**	O	O	O	O
SKC.WorldKnowl.PrbSolvingStrategy	*Plan*	O	O	O	O	O	O	O	O	O	O	O
(3.2.1)	*Progress*	O	O	O	O	O	O	O	O	O	O	O
	Goal	O	O	O	O	O	**A**	O	O	O	O	O
	Time	O	O	O	O	O	O	O	O	O	O	O

A = *Adding*; C = *Changing*; I = *Informing*

IWI3.3

> But we wouldn't publish the book in the same style or manner today because times have changed *and nonfiction books are made differently now.*

The single interaction for this IWI incident is shown below:

(65) 3.1.2.2.2:Summary:SY:C

Interaction 65. This IWI incident was rather atypically restricted to one interaction. The sentence by the problem solver ". . . and nonfiction books are made differently now." is another example of a summarization. In this instance, the summarization does not encompass a very large amount of text, substituting for a clause. For comparison, the part of the text that is summarized reads ". . . and with them the way in which authors and publisher approach juvenile nonfiction topics." Still, although little more than a restatement of the author's words, it differed sufficiently to be disqualified as reading and it does reduce somewhat the length and scope of the original. In the grid, the entry would be at the intersection of *Synthesizing* as OPERATOR and *Summary* of SUMMARY (3.1.2.2.2) for structure. Because the intersection of these aspects is currently presenting an A for TRANSFORMATION, this interaction will result in a change, thus the use of C. Table 4.14 shows the change that would result.

Table 4.14.
Effect of IWI3.3 on IWI Grid for Example Three

		OPERATOR	C	S	A	S	I	P	A	S	M	G	M
BRANCH AND ASPECT (BAS NBR)	TYPE		U	E	S	I	N	U	N	Y	O	R	A
SKC.InfoPrb.Know.WrkCns.Summary	*Summary*		O	O	O	O	O	O	O	C	O	O	O
A = *Adding*; C = *Changing*; I = *Informing*													

IWI3.4

And they might focus on one whole day. Whichever course they chose, the basic facts would emerge at appropriate points of the text, but the manuscript would be tight. [Underlines clause] And there would be at least one photograph at every page instead of two or three. [Underlines phrase] It would be large. [Underlines phrase] *and this is all in keeping with the trends that I've seen too, in nonfiction books where they're full of illustrations and don't have too much text thrown together.*

Interactions from this IWI incident are shown below:

(66) 1.1.1.2.2:Phrase:SI:A
(67) 3.1.2.1:Preexisting:IN:I
(68) 3.1.2.1:Developing:SY:A
(69) 3.1.2.1:Preexisting:SY:C

Interaction 66. IWI3.4 proceeds with more reading of the text. The first interaction that is obvious is the underlining of certain phrases in the information source. Marking is behavior that supports the OPERATOR *Signaling*. The structures that are underlined are represented by the structure LINGUISTIC (1.1.1.2.2), type *Phrase*. The TRANSFORMATION would be A for *adding*.

Interaction 67. The remark of the problem solver in this IWI instance indicates two different operations. One is that the participant is remembering something, which appears to be previously acquired knowledge which is brought to mind in the words ". . . in nonfiction books where they're full of illustrations and don't have too much text thrown together." This part of the remark gives rise to an entry in the grid under *Ingesting*, since remembering is a behavior of this OPERATOR. The information, or rather the knowledge, that is the object of the operator is *Preexisting*, a type under TOPICAL (3.1.2.1). Its TRANSFORMATION code will show I, for informing.

Interactions 68 and 69. The beginning of the remark ". . . and this is all in keeping with the trends that I've seen too, ..." ties the new material and the retrieved, preexisting material together by the behavior of integrating, a type of behavior grouped with the OPERATOR *Synthesizing*. The entry would reflect a TRANSFORMATION of C with the structure *Preexisting*, and an A with *Developing*, both types under TOPICAL (3.1.2.1) to show that each is affected by the integration.

Table 4.15 shows the entries.

Table 4.15.
Effect of IWI3.4 on IWI Grid for Example Three

BRANCH AND ASPECT (BAS NBR)	OPERATOR / TYPE	CU	SE	AS	SI	IN	PU	AN	SY	MO	GR	MA
Info.Seed.Form.PhysFormat.Linguistic	*Word*	O	O	O	O	O	O	O	O	O	O	O
(1.1.1.2.2)	*Phrase*	O	O	O	**A**	O	O	O	O	O	O	O
	Sentence	O	O	O	O	O	O	O	O	O	O	O
	Paragraph	O	O	O	O	O	O	O	O	O	O	O
	Non-cont. sent.	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.Topical (3.1.2.1)	*Preexisiting*	O	O	O	O	**I**	O	O	**C**	O	O	O
	Developing	O	O	O	O	O	O	O	**A**	O	O	O
A = *Adding*; C = *Changing*; I = *Informing*												

IWI3.5

> Four features that seem to be characteristic of [sic] new approach to juvenile nonfiction of all ages. Four key features are close focus in one aspect of the topic [Underlines phrase] that will serve to reveal other aspects. Concise, tightly written text. [Underlines phrase] Built-in emphasis on illustrations. [Underlines phrase] *And number four is* overall design of the book. [Underlines phrase] *So here we're back to talking about literary art in the broader sense of the word.*

Interactions shown in this IWI incident are listed below:

(70) 1.1.1.2.2:Phrase:SI:C
(71) 1.1.1.2.2:Sentence:GR:A
(72) 1.1.2:To-date:SY:A
(73) 3.1.2.2.1:Article:SY:C

Interaction 70. IWI3.5 also shows the behavior marking, which entails the same sequence as described above in IWI3.4. The entry would be the same as in Interaction 66, with a TRANSFORMATION of *changing.*

Interaction 71. The INFORMATION input to the next interaction is *Sentence*, a type under LINGUISTIC (1.1.1.2.2), and in this case, multiple sentences. The problem solver has been enumerating the content expressions in the sentences that correspond to the author's promised four features, and marks this by the phrase "And number four is . . . ." Since enumerating is a behavior of the OPERATOR *Grouping*, the

TRANSFORMATION type A will be entered at intersection of *Grouping* and *Sentence*.

Interaction 72. The next interaction is somewhat difficult to decipher. Because the example does include all that has been read of this source to date, it seems probable that the remark "So here we're back to talking about literary art in the broader sense of the word." may mean, now at this time and in this article, we're dealing again with something that was seen previously, although not in this interaction and not even in this source. This analysis implies that the INFORMATION type is *To-date* under CONTENT (1.1.2) and that the OPERATOR is *Synthesizing*, with TRANSFORMATION type A. The type *To-date* was chosen rather than either type *Preexisting* or *Developing* (both types under TOPICAL (3.1.2.1)) because there appears to be an inkling of alluding to the author of the source. The use of "we're" instead of "I'm" gives a hint of a partnership, and the only partner available is the author of the information. This choice shows that interpretation of an interaction is not yet rote nor well bounded. It is sometimes problematic to settle on one interpretation at the expense of others than appear close runners-up.

Interaction 73. There is one more interaction that appears to be available in the same remark. That is, there seems to be a relating of the CONTENT (1.1.2) information *To-date*, to the WORKING CONSTRUCTIONS aspect PERTINENCE (3.1.2.2.1), specifically *Article*. This would be represented by an entry of C in the intersection of *To-date* and the OPERATOR *Synthesizing*, which has already been done in this IWI incident, and in the intersection of *Article* and *Synthesizing*.

Table 4.16 reflects these interactions.

Table 4.16.
Effect of IWI3.5 on IWI Grid for Example Three

BRANCH AND ASPECT (BAS NBR)	OPERATOR TYPE	CU	SE	AS	SI	IN	PU	AN	SY	MO	GR	MA
Info.Seed.Form.PhysFormat.Linguistic (1.1.1.2.2)	*Word*	O	O	O	O	O	O	O	O	O	O	O
	Phrase	O	O	O	**C**	O	O	O	O	O	O	O
	Sentence	O	O	O	O	O	O	O	O	O	**A**	O
	Paragraph	O	O	O	O	O	O	O	O	O	O	O
	Non-cont. sent.	O	O	O	O	O	O	O	O	O	O	O
Info.Seed.Content (1.1.2)	*Individual topic*	O	O	O	O	O	O	O	O	O	O	O
	To-date	O	O	O	O	O	O	O	**A**	O	O	O
SKC.InfoPrb.Know.WrkCns.Pertinence (3.1.2.2.1)	*Info expression*	O	O	O	O	O	O	O	O	O	O	O
	Article	O	O	O	O	O	O	O	**C**	O	O	O

A = *Adding*; C = *Changing*; I = *Informing*

IWI3.6

> Visual look of nonfiction is especially important today. [Underlines phrase] *This is reminding of those -- what are they called? The close-up series, those books that have all full of photographs that are so beautiful. So how do you create a book like that is the question posed here.*

The interactions found in this IWI incident are shown below:

(74) 1.1.1.2.2:Phrase:SI:C
(75) 3.1.2.1:Preexisting:IN:I
(76) 3.1.2.2.2:Summary:SY:C

Interaction 74. Again, the problem solver has underlined (a type of marking behavior) a phrase in the interaction. The OPERATOR *Signaling* will show an C in its intersection with *Phrase*, a type of LINGUISTIC (1.1.1.2.2), since an earlier transformation is already recorded in the grid.

Interaction 75. The next interaction involves remembering, a behavior that supports the OPERATOR *Ingesting*. In this instance, it uses *Preexisting* (TOPICAL (3.1.2.1) as input information, thus inserting an I in the intersection of the two.

Interaction 76. The last sentence in the remark made by the problem solver is again a rewording of the information expression of the author, but is sufficiently different to warrant being considered a participant contribution. This interaction is very similar to the one identified in IWI3.3 (Interaction 65) above, and results in the same entry: a C at the intersection of the OPERATOR *Synthesizing* and the structure SUMMARY (3.1.2.2.2), type *Summary*.

Table 4.17 recaps the entries.

Table 4.17.
Effect of IWI3.6 on IWI Grid for Example Three

BRANCH AND ASPECT (BAS NBR)	TYPE (OPERATOR)	CU	SE	AS	SI	IN	PU	AN	SY	MO	GR	MA
Info.Seed.Form.PhysFormat.Linguistic	*Word*	O	O	O	O	O	O	O	O	O	O	O
(1.1.1.2.2)	*Phrase*	O	O	O	C	O	O	O	O	O	O	O
	Sentence	O	O	O	O	O	O	O	O	O	O	O
	Paragraph	O	O	O	O	O	O	O	O	O	O	O
	Non-cont. sent.	O	O	C	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.Topical (3.1.2.1)	*Preexisting*	O	O	O	O	I	O	O	O	O	O	O
	Developing	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.WrkCns.Summary	*Summary*	O	O	O	O	O	O	O	C	O	O	O

A = *Adding*; C = *Changing*; I = *Informing*

<u>IWI3.7</u>

> And let's look at some recent titles, *it says*, to help answer that question. *Talking about* Statue of Liberty Centennial, *and books that were made around that.* [Glances ahead in text] *And I'm going to skim this. I assume it's just going to be illustrating how these books include those four concepts that were outlined in the beginning.*

Interactions found in this IWI are shown below:

(77) 3.1.2.2.2:Summary:SY:C
(78) 3.2.1:Plan:MA:A
(79) 1.1.1.2.2:Paragraph:IN:I
(80) 3.1.2.2.4:Expectations:AN:C

<u>Interaction 77</u>. In this interaction, once again this problem solver summarizes while reading. The first sentence of the remark "Talking about Statue of Liberty Centennial and the books that were made around that." is a modified version of the author's expression, and appears to be

more concise and general than the original, although it is a close call. Thus, the structure SUMMARY (3.1.2.2.2), type *Summary* is once again changed by the OPERATOR *Synthesizing*, via the behavior of summarizing.

Interaction 78. At this point, the problem solver indicates strategizing, by remarking "And I'm going to skim this." The word 'this' appears to be referring to the upcoming text, since the intention seems to be addressed to a future action. The OPERATOR would be *Managing*, and the TRANSFORMATION would be A. The type *Plan* under PROBLEM SOLVING STRATEGY (3.2.1) would be the structure that is affected.

Interaction 79. The action that actually induced this interaction seems to be a glance at the rest of the paragraph whose content seems to provide another example of a children's book. *Paragraph* under LINGUISTIC (1.1.1.2.2) will be used as the INFORMATION structure for the OPERATOR *Ingesting*, with TRANSFORMATION code I.

Interaction 80. The last interaction in IWI3.7 is one in which the problem solver raises an expectation of the author's purpose for the next chunk of information. This is a forecasting behavior, reflected in OPERATOR *Anticipating*, and will show as an intersection with type *Expectations* in EXPECTATIONS (3.1.2.2.4). TRANSFORMATION is C since an earlier interaction has occurred.

Table 4.18 displays the entries for this IWI incident and Table 4.19 for the composite for the example.

Table 4.18.
Effect of IWI3.7 on IWI Grid for Example Three

	OPERATOR	C	S	A	S	I	P	A	S	M	G	M
BRANCH AND ASPECT (BAS NBR)	TYPE	U	E	S	I	N	U	N	Y	O	R	A
Info.Seed.Form.PhysFormat.Linguistic	*Word*	0	0	0	0	0	0	0	0	0	0	0
(1.1.1.2.2)	*Phrase*	0	0	0	0	0	0	0	0	0	0	0
	Sentence	0	0	0	0	0	0	0	0	0	0	0
	Paragraph	0	0	0	0	**I**	0	0	0	0	0	0
	Non-cont. sent.	0	0	0	0	0	0	0	0	0	0	0
SKC.InfoPrb.Know.WrkCns.Summaries	*Summary*	0	0	0	0	0	0	0	**C**	0	0	0
SKC.InfoPrb.Know.WrkCns.Expectations	*Expectations*	0	0	0	0	0	0	**C**	0	0	0	0
SKC.WorldKnowl.PrbSolvingStrategy	*Plan*	0	0	0	0	0	0	0	0	0	0	**A**
(3.2.1)	*Progress*	0	0	0	0	0	0	0	0	0	0	0
A = *Adding*; C = *Changing*; I = *Informing*												

Table 4.19.
Composite IWI Grid for Example Three - Using an Information Source

BRANCH AND ASPECT (BAS NBR)	OPERATOR TYPE	C U	S E	A S	S I	I N	P U	A N	S Y	M O	G R	M A
Info.Seed.Form.Literary Device (1.1.1.1)	*Metaphor*	o	o	o	o	o	o	o	o	o	o	o
	Analogy	o	o	o	o	o	o	o	o	o	o	o
	Example	o	o	o	o	**I**	o	o	o	o	o	o
	...	o	o	o	o	o	o	o	o	o	o	o
Info.Seed.Form.PhysFormat.Document	*Publisher*	o	o	o	o	o	o	o	o	o	o	o
(1.1.1.2.1)	*Publication date*	o	o	o	o	o	o	o	o	o	o	o
	Title	o	o	o	o	**I**	o	o	o	o	o	o
	...	o	o	o	o	o	o	o	o	o	o	o
	Author	o	o	o	o	o	o	o	o	o	o	o
Info.Seed.Form.PhysFormat.Linguistic	*Word*	o	o	o	o	o	o	o	o	o	o	o
(1.1.1.2.2)	*Phrase*	o	o	o	**C**	o	o	o	o	o	o	o
	Sentence	o	o	o	o	**I**	o	o	o	o	**A**	o
	Paragraph	o	o	o	o	**I**	o	o	o	o	o	o
	Non-cont. sent.	o	o	o	o	o	o	o	o	o	o	o
Info.Seed.Content (1.1.2)	*Individual topic*	o	o	o	o	o	o	o	o	o	o	o
	To-date	o	o	o	o	o	o	o	**C**	o	o	o
Info.PhysSource.Imperfections (1.2.1)	*Truncated word*	o	o	o	o	o	o	o	o	o	o	o
Info.PhysSource.Class (1.2.2)	*Info source doc*	o	o	o	o	o	o	o	o	o	o	o
	Problem Stmt	o	o	o	o	o	o	o	o	o	o	o
	...	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Task.Phy Product (3.1.1.1)	*Notes*	o	o	o	o	o	o	o	o	o	o	o
	Marks	o	o	o	o	o	o	o	o	o	o	o
	...	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Task.Cnstrt.Time (3.1.1.2.1)	*Session length*	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Task.Cnstrt.Answer	*Answer form*	o	o	o	o	o	o	o	o	o	o	o
(3.1.1.2.2)	*Answer length*	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Task.Cnstrt.Resources	*Resource avail*	o	o	o	o	o	o	o	o	o	o	o
(3.1.1.2.3)	*Personal Property*	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Know.Topical (3.1.2.1)	*Preexisting*	o	o	o	o	**I**	o	o	**C**	o	o	o
	Developing	o	o	o	o	o	o	o	**A**	o	o	o
SKC.InfoPrb.Know.WrkCns.Pertinence	*Info expression*	o	o	o	o	o	o	o	o	o	o	o
(3.1.2.2.1)	*Article*	o	o	o	o	o	o	**A**	**C**	o	o	o
SKC.InfoPrb.Know.WrkCns.Summaries	*Summary*	o	o	o	o	o	o	o	**C**	o	o	o
SKC.InfoPrb.Know.WrkCns.InfoText	*Scope of article*	o	o	o	o	o	o	o	o	o	o	o
(3.1.2.2.3)	*Clarity of expr*	o	o	o	o	o	o	o	o	o	o	o
	Validity of expr	o	o	o	o	o	o	o	o	o	o	o
SKC.InfoPrb.Know.WrkCns.Expectations	*Expectations*	o	o	o	o	o	o	**C**	o	o	o	o
SKC.InfoPrb.Situation (3.1.3)	*Materials*	o	o	o	o	o	o	o	o	o	o	o
	Place	o	o	o	o	o	o	o	o	o	o	o
	Time	o	o	o	o	o	o	o	o	o	o	o
SKC.WorldKnowl.PrbSolvingStrategy	*Plan*	o	o	o	o	o	o	o	o	o	o	**A**
(3.2.1)	*Progress*	o	o	o	o	o	o	o	o	o	o	o
	Goal	o	o	o	o	o	**A**	o	o	o	o	o
	Time	o	o	o	o	o	o	o	o	o	o	o
SKC.WorldKnowledge.Self-knowledge	*Cognitive style*	o	o	o	o	o	o	o	o	o	o	o
(3.2.2)	*Grammar*	o	o	o	o	o	o	o	o	o	o	o

A = *Adding*; C = *Changing*; I = *Informing*

CONCLUSION

This completes the discussion of the extended examples and of the development of the frame model. The intent of the examples was to present a working picture of the model, showing how its parts interact.

Now that all the pieces and relationships have been identified, the next step is to evaluate the model's contribution to understanding personal knowledge construction.

CHAPTER 5. CONCLUSION AND FUTURE DIRECTIONS

EVALUATION OF THE MODEL'S LIMITATIONS AND CONTRIBUTIONS

Introduction

At this point, it is appropriate to review the objectives of the study in preparation for examining the merits of the model. Briefly, the basic objective was to describe the ongoing process of constructing personal knowledge, with particular attention to the phenomenon of interacting with information. Problem solving, defined within the paradigm of states and change operators, provided the goal for the exploration and description of interactions. The specific goal became to identify and describe structures and operators that comprised the states and transformation agents of information problem solving.

A model of this phenomenon has been presented. Not only has it identified certain structures and operators but also it has configured their structural relationships. Interactions among the structures of the three major branches, which encompass the observed nature of information, interactions, and knowledge components of the problem solver, were demonstrated through presentation of several examples.

Having described a model, it is time to step back and look at its operating characteristics or, more specifically, its contributions and limitations. In the interests of establishing its boundaries before asserting its worth, the model's limitations will be discussed before its contributions.

Limitations

Type of Situation and Task

The study concentrated on a specific type of information problem. It used as its situation the circumstance of a student using written information sources to acquire knowledge about a topic and as its task writing a short response to an information problem derived from a request generated by the researcher.

Many information problem solving situations are like the one depicted, although without the cachet of being observed. Still, the act of using written sources in an educational environment for a prototypical educational activity constitutes only one application of constructing personal knowledge through interacting with information. There are numerous others that differ from this one. For example, information or knowledge needs that develop internally for purposes other than responding to an externally imposed educational requirement may activate previously undisclosed model variables. Activities undertaken in response to a job requirement, a personal hobby, a community commitment or a personal obligation may motivate variants as well as divergent aspects in all three branches of the model.

Type of Subjects

In addition to situational homogeneity, the participating subjects displayed a certain sameness as well. The volunteers all shared one important attribute, that of being expert information problem solvers.

It is not uncommon to find differences at the cognitive level in the performance of expert, novice and naive practitioners of a complex knowledge intensive activity or process. The study subjects represent a cohort of frequent users of the process depicted in the model, but they may represent only one end of the experience continuum. Occupying the upper end of the continuum, they may have compiled some of the processes that are involved and may be able to implement them with little or no attention. Since the model is developed from the items that attain at least a modicum of attention from the problem solver, less experienced subjects may identify other structures or operations that are attended to by them, but which are not, and thus go unreported, by the more experienced subjects.

Empirical, Incremental Derivation

Because the model was developed from the observations of one sample of problem solvers, it is possible that a number of structures which were not identified might have been found if a different sample was used. That is, the structures and operators that were included in the model were resident in the collected reports of these problem solvers; other structures and operators may exist that were not produced by this particular combination of information source, information problem and information problem solver. A type of operation may not have been undertaken or a type of structure may not have become apparent because none of these problem solvers encountered information that prompted that (unknown) interaction at that time and place.

In addition, the incremental development of a model raises the question of when to stop considering new instances. An underlying tenet of the practice of building groups by constant comparison calls for processing instances until the developing categories are saturated. Even so, it is very probable that additional categories may surface in subsequent examination of supplementary and diverse instances of the phenomenon. This model, like all models, was developed based on a finite group of instances. Further experience with the variations of the phenomenon will almost certainly uncover aspects that had not been revealed in earlier examples, as the modeler's prolonged experience with the model also will produce modifications and enhancements. This study chose to concentrate on examples that were similar in order to improve its chances of identifying the basic structures and operators. This choice limited the variability of the instances of the phenomenon and thus to some extent the model's ability to generalize to those variations.

Descriptive versus Productive Model

The model that was produced will not translate directly into a computer model. A computer model, to avoid the criticism that the modeler is acting as homunculus, must be able to accept and process data independently. That is, the data must present sufficient information to a processing module for it, independently of outside guidance or direction, to choose and implement appropriate transformations and operations, thus producing apt behavior of the model components. It is a productive model, in the sense that it will process input and produce its own output.

The frame model developed in this study is a descriptive model of a phenomenon. That is, it describes the components and their relationship at a structural level. It does not specify how input information will determine which operator will be selected and processed. It is not a theory of continuous interacting with information processing over time but rather a model describing interactions, one at a time. To demonstrate the interactions in the extended examples, the modeler made necessary processing decisions on its behalf, based on rules and inferences not included in the frame model. For example, the modeler identified the appropriate operator from the response that the participant had made. The production rules, if one uses the language of expert systems, were provided by the modeler, not the model; the model provided objects and their content for manipulation. The model does not address the rules for moving through a source document; rather, it describes an interaction as a result. In an operating model, one would expect the model to have routines for choosing an operator for use. At the level of description presented in this model, however, the correlations to develop the decision making apparatus are not available. The intent of the study, however, was not to develop a computer model with its implied independence in decision making and processing, but rather to discover and move toward the specification of appropriate structures and interactions.

It is an open question as to whether information by itself would be sufficient for determining an operator for a given problem solver. As data from this study show, different problem solvers responded to different information, and responded differently to the same information. It seems unlikely that exact specification of a necessary link between a given input and process will be possible if input is limited to information only. Information, in the sense used in this model, is too indeterminate to justify a choice of operator based on itself only. Too many possible responses to any one given instance of input exist. The fact that a single human situated in a time and place does not produce all the possibilities in an instance does not nullify their existence. The fact that different problem solvers produced different interactions when encountering the same information is an existence proof of at least some of the alternatives that may be sanctioned by the information. The key question of what warrants the choice that is made by an individual problem solver remains. Why this interaction and not some other choice?

That is not say that it will remain forever impossible to build a self-acting model of interacting with information. It is becoming increasingly clear that a model may move closer to the goal of independent action if input to an interaction includes evidence and clues to the context of the encounter and these clues are accommodated in the model's decisions.

Verbal Reports

Another limitation of the study derives from the use of verbal reports based on short term memory. For a number of reasons, verbal reports are incomplete. To begin with, some thoughts are not verbal in nature, and if reported at all, represent a conversion from a nonverbal form. An example of a nonverbal form is an mental image or a picture that is being viewed. As Ericsson and Simon point out, verbalizing about images or pictures requires transforming one's thought into a verbal form, and this need to transform may introduce variations in task production and completion. Although there was not much in the way of image or picture stimuli in the information sources, it is possible that some of the metaphors created nonverbal images, and that processing of these images occurred nonverbally.

For some persons for whom verbalizing is not their preferred mode of thinking, thinking aloud would be less natural than for those who are verbalizers. A participant who remarked upon his thinking mode after completing his participation, and unfortunately, after the video recorder was disengaged, is an example of preferring a mode other than verbal. His comment was that he did not think verbally, but graphically. The comment indicates that the participant found verbalizing less natural than others would. Because of this, his reports may differ from reports from someone who verbalizes easily.

Of course, another limitation is that, even for verbalizers, one may not continuously report. Interruptions and pauses occurred in all the reports. The researcher does not have access to all of the thinking when this occurs. Pauses and quiet periods seem very likely during reading, even though participants were not asked to read aloud, but rather to report what was in their minds, including what they were reading. Since it is known that a reader does not fixate every word, skipping some of the function words for example, reading is likely to have blanks and changes within sentences. And, since the participants might get caught up in what they are reading, they might forget to say aloud what they were reading. Most adult readers have spent a lot of time and effort learning to read silently. This exercise of verbal reporting must overcome a fairly well ingrained habit for reading, something that is not likely to be perfected in the short time period of the recording session.

Contributions

Within the limitations that bound it, the model contributes to the understanding of personal knowledge construction by providing new insights in several areas.

Ascertaining Phenomenon Components

The most obvious contribution is the one that explicitly fulfills the objective of the study. Analyses were able to penetrate the unity of the integrated phenomenon of personal knowledge construction, with the result that at least some of its underlying structures and operations have been revealed. The model advances toward a clearer understanding of the process by distinguishing constituents of the procedure. Separation into elemental parts fosters an ability to focus attention at will on a component, giving impetus to further refinements and a better grasp of its nature and function.

The structures and operators that were defined do exist, although there is no claim that the model is complete or that other structures do not also exist. The aspects of information that were attended to, the types of operators that were implemented, and the structures that embody the constructions of the problem solver are clearly evident in the data. They now become available for further study and experimentation.

It is worth examining the position of findings in an exploratory work such as this in relation to findings from other, related studies. It is encouraging to discover a degree of convergence, which serves to demonstrate and to validate shared findings.

The structures depicted in INTERACTING WITH INFORMATION have been found to come together with findings reported concisely in Barry (1994). An information interaction underlies Barry's study also, although in Barry, the task is to make sense of the information as part of selecting a source. The tasks in the two studies appear to be near neighbors on a continuum of seeking, retrieving and using information, although Barry's task concentrates on retrieving and this study, on using.

Barry's study dealt with predicting pursuit or non-pursuit of a source based on examination of surrogate representations. Her procedure asked information problem solvers to examine several versions of topically relevant surrogates and three actual documents. They were to mark "any portion of the stimulus materials that prompted a reaction to pursue some aspect of the document." and also "any portion of the stimulus materials that indicated something the respondent would not pursue" (p. 153). Following the respondent's examination of all the stimulus materials, Barry interviewed each in order to elicit the respondent's comments about the marked portion, continuing "until the respondent was offering no new reasons for having marked an item" (p. 153). Thus, the thrust of the activity for Barry's respondents was to predict their future activity with that source based on their examination and assessment of various versions of surrogate information about it.

This scenario presumes that, to some extent, Barry's respondents are interacting with information, although the focus of problem solving differs. One should not be surprised to see overlap between Barry's criteria and the IWI components found in this study. And in fact, there is some replication of features. Barry's content analysis and subsequent grouping of responses produced seven broad categories of criteria. Of those, IWI shares to some extent with all but two categories. For example, the IWI elements CONTENT (1.1.2) and INFORMATION TEXT (3.1.2.2.3) are very similar to Barry's Criteria Pertaining to the Information Content of Documents, considered to be criteria which ". . .

do seem to be primarily identifying some characteristics of the information itself" (p. 153).

In another comparison, an OPERATOR was a match for a category. *Selecting*, which includes behaviors such as agreeing, liking, and choosing, and Barry's Criteria Pertaining to the User's Beliefs and Preferences, which includes subjective accuracy/validity and affectiveness, which are emotional responses to any aspect of the document, appear to be concerned with the same characteristic of the user's beliefs and personal preferences.

The matches are not perfect, most likely because the two researchers group and interpret similar phenomena in different terms. Still, the findings support each other. More importantly, they support the reasonable expectation that interacting with information for the related purposes of retrieving and using information share related cognitive structures and processes.

Context

The second contribution made by this study has to do with the concept of context. Context is a concept that is not well defined, but is still rather meaningfully applied.

According to Webster's New World Dictionary, the origin of context is from the Latin *contexere*, meaning a joining together, derived from the combination of weaving and together. The key element in modern use of the word seems to be that of a surround that determines the exact meaning of that which it surrounds. Context is frequently explained as the situation or circumstances relevant to a particular event or creation. Key here is the term relevant, usefully interpreted to mean pertaining to the matter at hand. In essence, then, context is that which surrounds and bears upon an event at hand.

How does this study add to an understanding of context for the phenomenon of interacting with information? If context surrounds and bears upon an event, it would participate in characterizing and describing that event. One would include context in which an event occurred in order to insure a complete description of the event and to make available the elements of the surround that contribute to the event.

To do this, it is useful to have some idea of what contextual features bear on an event. Since many different features may occur in the surround, it is sensible to distinguish those that are of importance for the matter at hand. This study has fostered insight on context for the event of interacting with information. By collecting a considerable, although by no means complete, portion of a girdling context, the study provides the opportunity for recognizing influences that pertain in the event, rather than relying upon an intuitive conception of what contextual features apply.

This study highlights a number of features of context, including both mental structures and operators. The problem solvers themselves mark these features by the very act of using them during an IWI instance. It is the observation of structures and operators intertwined in the event that yields the conclusion that these features bear on the event as contextual elements. Observation of this interleaving provides significant empirical substantiation to the concept of contextual effects. Since there are a great variety of influences available, being able to point to those that have actually been seen to exert influence is one way to winnow contextual features and to serve as a guide to those of interest in future study.

Note that it is the effect of content of an IWI structure on the solver's mental knowledge base that is actually observed. A structure is an abstraction that serves to establish a type or kind, but is not itself an instance of the type and does not produce an effect by itself. Structures are associated with each other by relations such as *part-of* or *is-a*. The connections between structures are developed over time, as an individual matures and learns. It is partly because of its relations to other structures that the content of a structure is unique to an individual. No two problem solvers have the same content within a structure and no two have identical connections between structures. For that matter, it is likely that a problem solver will not reflect the exact configuration of structures and content at two different times.

Given this, is it of value to look at the structures, if they are the carriers rather than the actuators of an event? While no two individuals have the exact same configuration of structures and relations, there is definitely overlap among concepts and configuration among problem solvers. By allowing for the presence of a structure, and by determining the content of that structure for the problem solver under question, one might in theory be able to determine what happens next. As Kelly (1955) said in one of his corollaries to his theory of personal constructs, "To the extent that one person employs a construction of experience which is similar to those of another, his psychological processes are similar to those of the other person" (p. 90). For example, it is instantiation of these structures which is the goal of knowledge engineers as they attempt to capture the knowledge content of an expert for those structures which are implicated in the solution of the problem being modeled.

As another example, in well-structured problems, it is possible, by doing a task analysis, to establish the exact knowledge needed by a problem solver to solve a problem. Newell and Simon (1972), in their study of subjects doing cryptarithmetic, exemplify this approach. A subject's behavior, including the exact content of his or her mental structures concerning the elements of the problem, can be graphed in a detailed fashion, partly because the structures of concern are known and partly because the operations on those structures are also known. This technique highlights the need to understand both knowledge structures and available operators.

The ability to map state components and necessary operators does not exist for complex, ill-structured problems, or at least, not to the extent that it exists for well-structured problems. As a first step to a task analysis, discovering appropriate structures and operators for a complex problem may lead to an ability to analyze its process and procedures.

This study has compiled basic structures and operators for the complex circumstances of the information problem. Although no claim is made that every and all structures or operators has been found, there is now a framework within which to work and explore. Context for interacting with information incorporates the elements in the frame model. Since context is a surround of linked influences bearing on the matter at hand, to change an element is to change the context. Operators are the agents and structures the objects of change; context is among the harvest of their interaction. The model provides a means of viewing and capturing context fabricated from the contributing interactions.

Context is of particular importance to information science because the field relies upon relevance as a foundational tenet. The user-centered view of relevance is heavily invested in the concept of relevance within the context of an individual information seeker with a specific information need and problem. An example of this concept of relevance in action is proposed by Harter (1992). Harter adapted Sperber and Wilson's (1986) relevance in communication, termed by him psychological relevance, to the field of information retrieval. It posits that relevance is the result of an assumption causing contextual effects within a problem solver's current context. Contextual effect is defined to mean that an assumption may be added to, strengthened, weakened or deleted from the knowledge base of the information user.

Within the IWI model, the contextual effects that are identified in psychological relevance are found in several of the types of OPERATOR. For example, operators such as *culling, selecting* and *assessing* deal with strengthening and weakening the perceived value of an assumption while *synthesizing* adds new combinations of knowledge to the problem solvers' data bases.

Harter applied psychological relevance in an extended example that discussed the possible contextual effects that could occur in the presence of a retrieved item given different contexts of the searcher. Harter varied the context of the searcher in several ways: a retrieved item might be novel to searcher; a searcher might be looking for a lack of citations; the searcher might be dealing with a known author of a retrieved item; or the retrieved citations might not concern the topic but still cause contextual effects. In the IWI frame model these circumstances could be represented in structures such as TASK (3.1.1), DOCUMENT (1.1.1.2.1), TOPICAL (3.1.2.1), and PROBLEM SOLVING STRATEGY (3.2.1), particularly the type *Goal.*

FUTURE DIRECTIONS

This section presents areas of future work that follow from the model's present condition.

Model Extension

As was pointed out in the section on limitations, the data used to develop the model did not include much variety of situations or subjects. The first change to the model should be along the lines of extending its generalizability by incorporating the effects of different types of situations and subjects.

What may be expected by extending data collection to new situations, tasks and subjects? Based on the structures in the basic model, one could anticipate the discovery of additional *types* that reflect altered and distinct circumstances. Intuitively, one would expect differences; objectively, one would collect data and rely upon it to identify the changes or additions to the aspects and types of the basic model.

Situations

Circumstances may be varied by selecting situations that differ from the educational one used in the study. The vignettes presented in

Chapter One are examples of different purposes for which people use information to construct knowledge. Gathering information about problem solvers' interactions in these environments will enrich the basic aspects and types. For example, by examining a personal use, such as to investigate the symptoms and recovery for a disease afflicting a family member, one might recognize an aspect of SITUATION (3.1.3) that could be called motivation. The data examined for this study did not reveal an motivating urge, although it is reasonably certain that there was a motivation of some sort. A personal circumstance might elicit an interaction that reveals an underlying drive for undertaking information problem solving.

Again, tracking the interactions of a professional user in a professional work environment is likely to uncover somewhat different factors. CONSTRAINTS (3.1.1.2) might be broadened to accommodate professional ethics or acceptable discovery methods. SITUATION might include personal preferences about one's working environment, including choices about time, place and means for doing the work. Not everyone works at a desk or table; nor does everyone prefer the same time of day for their more important undertakings.

A recreational use of information problem solving may elicit new aspects because one is normally deeply involved in the topic of a hobby. Hobbyists' strong motivation about their topic may engender a different pattern of interactions.

Tasks

In addition to varying the situation, one might change the task. A change from the need to produce a written response to some other end requirement for the information will certainly produce additions in PHYSICAL PRODUCT (3.1.1.1) and likely in CONSTRAINTS (3.1.1.2), reflecting the variation in end purpose. It would be useful to include a task of a very unconstrained nature such as reading with no particular immediate purpose, as, for example, reading to remain current in one's professional literature.

Subjects

Another type of model extension would be to vary the type of subjects that are studied. This study concentrated on expert information problem solvers doing a well-practiced task. It would be very useful to expand the subject base to include non-experts. It seems likely that different subjects might reveal other WORKING CONSTRUCTIONS, particularly if the subjects are less experienced at the task of information problem solving than the sample for this study.

The reasoning behind using less expert practitioners is that experts have usually compiled many procedures and do not attend to them, whereas a beginner is more likely to execute a new procedure step by step, with strongly focused attention. A source of non-expert subjects for information problem solving may be students in junior high school, who are just beginning to learn to use information sources in pursuit of an information problem solution. Even junior high students are familiar with and have employed interacting with information for some time; but, their level of experience in information problem solving is less, and thus not as automatized as that of a more experienced problem solver. For an even more unpracticed performance, one could approach students who are just beginning to read.

Category Verification

It would be useful to refine the coding scheme and apply it to new and existing instances of interacting with information. This exercise is useful for two reasons. First, by assigning each IWI and interaction to a category, an indication of frequency of occurrence of the different aspects and types could be determined. Even simple frequencies would be informative to a researcher.

Secondly, while categories have been ascertained from the data for the basic model, applying these categories to new data remains to be done. As a first step, it must be determined whether the definitions that were developed are reliably distinguished from each other and in data by coders other than the code creator. Although one attempts to capture in definitions the tacit knowledge that is applied to distinguish categories, a coder who has prepared the definitions may be unaware of applying an overlooked characteristic tacitly or may be able to gloss over a discrepancy or misleading construction that another person would notice and find confusing.

By testing the coding instructions one is able to confirm the understandability of the category definitions and to check on their match to data incidents. The simple procedure of two or more coders independently coding the same data followed by the computation of the proportion of agreement in category assignments is a typical method for verifying categories and coding instructions. One would be able to massage the definitions of the categories and, indeed, the categories themselves, to achieve the distinctions needed to achieve the desired level of inter-coder reliability. If one is using data not involved in the original definition of the categories, one also achieves some confirmation of categories as well as confidence in the coding instructions.

Questions for the Future

The data that were collected for this study are immense in quantity. The analyses that have been done over these data are only a small set of the analyses that could be done. Profitable use of the data could be made in exploring a number of questions.

Shape of a Session

Among the questions that could be approached using the existing data is one about the shape and form of an information problem solving session itself. Attention here has been focused on the actual information interaction but has virtually ignored the session sequence and process as a whole. Although three partitions of the session were identified, very minimal attention was given to them as units. In particular the start up and writing portions were examined very sparingly.

It would be beneficial to examine each part of a session as a process characterizing not only its manifested behaviors but also its interactions with the other parts. Examination is likely to uncover variations in procedural strategy and provide information about decision making and choice over the life of a problem solving experience. A number of questions come to mind. What are the lengths of the parts of the sessions? Is there evidence of session strategy or is strategy rather locally contained? What are the different strategies shown for start up, for document use, for writing?

Pertinence Behavior

A second question that could be explored using this data is the pertinence behavior of problem solvers. Among the data collected were the problem solvers' post-session evaluations of usefulness in solving the information problem for each source. It would be valuable to examine the problem solvers' treatments and use of their most or least useful documents during problem solving. A number of questions could guide the examination. Did these documents garner more attention? Did they engender more actions of a particular operator? Were there differences in the kind of operators that were implemented? Is there a difference in their length of study or in the number of interactions that occurred?

The question of pertinence may be extended to explore the expressions of pertinence that were given in IWI incidents. What kinds of expressions were used? Do the expressions made during problem solving correspond to the rating given at the conclusion?

Relationship of IWI and Answer

A third area that could be addressed concerns the relationship between interactions and the quality of the answer. The written answers have not been examined at all. It must be remembered that each problem solver developed an answer that is ultimately of value to him or her. Because of this, it is not necessarily true that the best answer as determined by an objective jury is the best answer for the information problem, which is connected to the individual problem solver. Still, questions such as the following arise and may provide serviceable information about information problem solving. Is there a definite relationship between the use of particular operators and the quality of the answer? Is there evidence of strategic behavior resulting in a better quality answer?

CONCLUSION

In many respects, the frame model confirms knowledge of reading and text comprehension that was presented in Chapter Two. Elements of INFORMATION, for example, that served as stimuli included features of words, words, phrases, sentences and continuous text. These all precipitated problem solving operations, as evident in the eleven OPERATOR types. These OPERATORs also supported the processes seen in text comprehension, such as integration of ideas across sentences, development of gist, and influences from the situation and task.

This study moves toward an understanding of the phenomenon of interacting with information. By showing the types of knowledge structures and operations that actually occur, it opens a window into the cognitive processes of converting public information into private, personally constructed knowledge. It provides a foundation upon which to construct a more elaborate comprehension of cognition and relevance.

APPENDIX A. BRANCHES, ASPECTS, AND TYPES

The frame model for Interacting with Information is presented here in outline form. **Branches** are the three main components. Each subordinate aspect in the frame model is numbered; *types* are not.

Branch and Aspect Level Number	Branch, Aspect and Types
0	Interacting with Information
1	**Information**
1.1	Seed
1.1.1	Form
1.1.1.1	Literary Device
	Metaphor
	Analogy
	Example
	Quotation
	Acronym
	Rhetorical Question
	Personal name
1.1.1.2	Physical Format
1.1.1.2.1	Document
	Publisher
	Publication date
	Title
	Subheading
	Table or chart
	Footnote
	Abstract
	Author
1.1.1.2.2	Linguistic
	Word
	Phrase
	Sentence
	Paragraph
	Non-contiguous sentences
1.1.2	Content
	Individual topic
	To-date
1.2	Physical Source
1.2.1	Imperfections
	Truncated word

Branch and Aspect Level Number	Branch, Aspect and Types
1.2.2	Class
	Information source document
	Problem statement
	Set of documents
	Oral
2	**Interaction**
2.1	Operator
	Culling (CU)
	Eliminating
	Setting aside
	Disagreeing
	Selecting (SE)
	Choosing
	Agreeing
	Liking
	Spotting
	Noting
	Assessing (AS)
	Evaluating
	Guessing
	Questioning
	Confusing
	Signaling (SI)
	Marking
	Heeding
	Ingesting (IN)
	Reading
	Receiving
	Listening
	Remembering
	Pursuing (PU)
	Asking
	Seeking
	Anticipating (AN)
	Forecasting
	Predicting
	Synthesizing (SY)
	Relating
	Comparing
	Integrating
	Summarizing
	Elaborating
	Commenting

Branch and Aspect Level Number	Branch, Aspect and Types
	Modifying (MO)
	Editing
	Revising
	Grouping (GR)
	Enumerating
	Sorting
	Managing (MA)
	Strategizing
	Reviewing
	Accommodating
	Metacognitive thinking
	Emoting
2.2	Transformation
	Adding
	Changing
	Informing
3	**Solver's Knowledge Components**
3.1	Information Problem
3.1.1	Task
3.1.1.1	Physical Product
	Notes
	Marks
	Answer
	Revised answer
3.1.1.2	Constraints
3.1.1.2.1	Time
	Session length
3.1.1.2.2	Answer
	Answer form
	Answer length
3.1.1.2.3	Resources
	Resource availability
	Personal property
3.1.2	Knowledge
3.1.2.1	Topical
	Preexisting
	Developing
3.1.2.2	Working Constructions
3.1.2.2.1	Pertinence
	Information expression
	Article
3.1.2.2.2	Summary
	Summary

Branch and Aspect Level Number	Branch, Aspect and Types
3.1.2.2.3	Information Text
	Scope of article
	Clarity of expression
	Validity of expression
3.1.2.2.4	Expectations
	Expectations
3.1.3	Situation
	Materials
	Place
	Time
3.2	World Knowledge
3.2.1	Problem Solving Strategy
	Plan
	Progress
	Goal
	Time
3.2.2	Self-knowledge
	Cognitve style
	Grammar

APPENDIX B. INTERACTING WITH INFORMATION (IWI) DISPLAY GRID

The IWI Display Grid has four parts.

Part one consists of the heading, which arrays in columns the OPERATOR types of the branch INTERACTION.

Part two consists of row entries for aspects and types in the branch INFORMATION; part three, those for SOLVER'S KNOWLEDGE COMPONENTS.

Part four, the circles, are the intersections of the OPERATOR and types from INFORMATION and SOLVER'S KNOWLEDGE COMPONENTS.

To save space, entries are abbreviated; in a few cases, the Branch and ASpect (BAS) number is not shown. For the full form of an entry, refer to Appendix A.

BRANCH AND ASPECT (BAS NBR)	OPERATOR TYPE	C U	S E	A S	S I	I N	P U	A N	S Y	M O	G R	M A
Info.Seed.Form.Literary Device (1.1.1.1)	*Metaphor*	O	O	O	O	O	O	O	O	O	O	O
	Analogy	O	O	O	O	O	O	O	O	O	O	O
	Example	O	O	O	O	O	O	O	O	O	O	O
	Quotation	O	O	O	O	O	O	O	O	O	O	O
	Acronym	O	O	O	O	O	O	O	O	O	O	O
	Rhetorical quest	O	O	O	O	O	O	O	O	O	O	O
	Personal name	O	O	O	O	O	O	O	O	O	O	O
Info.Seed.Form.PhysFormat.Document (1.1.1.2.1)	*Publisher*	O	O	O	O	O	O	O	O	O	O	O
	Publication date	O	O	O	O	O	O	O	O	O	O	O
	Title	O	O	O	O	O	O	O	O	O	O	O
	Subheading	O	O	O	O	O	O	O	O	O	O	O
	Table or chart	O	O	O	O	O	O	O	O	O	O	O
	Footnote	O	O	O	O	O	O	O	O	O	O	O
	Abstract	O	O	O	O	O	O	O	O	O	O	O
	Author	O	O	O	O	O	O	O	O	O	O	O
Info.Seed.Form.PhysFormat.Linguistic (1.1.1.2.2)	*Word*	O	O	O	O	O	O	O	O	O	O	O
	Phrase	O	O	O	O	O	O	O	O	O	O	O
	Sentence	O	O	O	O	O	O	O	O	O	O	O
	Paragraph	O	O	O	O	O	O	O	O	O	O	O
	Non-cont. sent.	O	O	O	O	O	O	O	O	O	O	O
Info.Seed.Content (1.1.2)	*Individual topic*	O	O	O	O	O	O	O	O	O	O	O
	To-date	O	O	O	O	O	O	O	O	O	O	O
Info.PhysSource.Imperfections (1.2.1)	*Truncated word*	O	O	O	O	O	O	O	O	O	O	O
Info.PhysSource.Class (1.2.2)	*Info source doc*	O	O	O	O	O	O	O	O	O	O	O
	Problem Stmt	O	O	O	O	O	O	O	O	O	O	O
	Set of documents	O	O	O	O	O	O	O	O	O	O	O
	Oral	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Task.Phy Product (3.1.1.1)	*Notes*	O	O	O	O	O	O	O	O	O	O	O
	Marks	O	O	O	O	O	O	O	O	O	O	O
	Answer	O	O	O	O	O	O	O	O	O	O	O
	Revised answer	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Task.Cnstrt.Time (3.1.1.2.1)	*Session length*	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Task.Cnstrt.Answer (3.1.1.2.2)	*Answer form*	O	O	O	O	O	O	O	O	O	O	O
	Answer length	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Task.Cnstrt.Resources (3.1.1.2.3)	*Resource avail*	O	O	O	O	O	O	O	O	O	O	O
	Personal Property	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.Topical (3.1.2.1)	*Preexisting*	O	O	O	O	O	O	O	O	O	O	O
	Developing	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.WrkCns.Pertinence (3.1.2.2.1)	*Info expression*	O	O	O	O	O	O	O	O	O	O	O
	Article	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.WrkCns.Summaries	*Summary*	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.WrkCns.InfoText (3.1.2.2.3)	*Scope of article*	O	O	O	O	O	O	O	O	O	O	O
	Clarity of expr	O	O	O	O	O	O	O	O	O	O	O
	Validity of expr	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Know.WrkCns.Expectations	*Expectations*	O	O	O	O	O	O	O	O	O	O	O
SKC.InfoPrb.Situation (3.1.3)	*Materials*	O	O	O	O	O	O	O	O	O	O	O
	Place	O	O	O	O	O	O	O	O	O	O	O
	Time	O	O	O	O	O	O	O	O	O	O	O
SKC.WorldKnowl.PrbSolvingStrategy (3.2.1)	*Plan*	O	O	O	O	O	O	O	O	O	O	O
	Progress	O	O	O	O	O	O	O	O	O	O	O
	Goal	O	O	O	O	O	O	O	O	O	O	O
	Time	O	O	O	O	O	O	O	O	O	O	O
SKC.WorldKnowledge.Self-knowledge (3.2.2)	*Cognitive style*	O	O	O	O	O	O	O	O	O	O	O
	Grammar	O	O	O	O	O	O	O	O	O	O	O

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