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ABSTRACT

This paper presents an instructional model for thinking skills and discusses implementing the model. Based on a unitary theory of human cognition and some basic assumptions about the conditions for successfully intervening in public education, the model can be implemented at any grade level within any instructional framework. Currently used models for thinking skills instruction are briefly reviewed. Then, a unitary model of cognition is translated into an instructional model of thinking skills which can be taught and reinforced in instructional contexts. Six general categories of thinking skills are considered: (1) a general procedure for increasing task efficiency; (2) recognition and encoding procedures; (3) storage and retrieval procedures; (4) matching procedures; (5) procedures for building new cognitive structures, and (6) executive system principles. Four major implications of the unitary model for instruction and curriculum are discussed. (RH)

A UNITARY MODEL OF COGNITION AND INSTRUCTION IN HIGHER ORDER THINKING SKILLS

by

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INTRODUCTION

The need for direct instruction in thinking is evidenced from many quarters. The Education Commission of the States in a report entitled The Information Society: Are High School Graduates Ready? (1982), states that "survey results indicate that today's minimum skills are demonstrated successfully by a majority of students. Higher order skills, however, are achieved only by a minority of 17-year-olds. If this trend continues, as many as two million students may graduate in 1990 without the skills necessary for employment in tomorrow's marketplace." (p.12). Similarly, the presidentially commissioned report, A Nation at Risk (1983), in its list of implementing recommendations identifies higher level thinking skills that should be more rigorously addressed.

The perceived need for instruction in thinking skills is partially due to the growing national awareness that society has and is changing rapidly -- skills that were appropriate 15 years ago no longer prepare students for the world outside of school. Such popular works as Megatrends (Naisbitt, 1982) and In Search of Excellence (Peters and Waterman, 1982) have implied that the very fabric of the business world has shifted from an emphasis on goods to an emphasis on information. That is, the commodity of the present and the future is information. Forbes, (1984) states that technology is both creating and destroying jobs. Many clerical and middle management positions are being fazed out with high tech replacements. However, the total number of jobs is increasing as technology opens new work vistas. In short, the changes in society are accelerating so rapidly that it is difficult if not impossible to predict precisely what content to teach students if we define content as factual knowledge. The implication for education is that we must teach students how to process information; how to become learners.

Concurrently work in the cognitive sciences has witnessed breakthroughs in our understanding of human cognition. For example, researchers within artificial intelligence have developed computer simulations that can answer literal and inferential questions (Lehnert, 1978) and comprehend complex information presented in language form (Schank et al, 1975). Educators are only now beginning to translate computer based information processing strategies into instructional techniques. We might say, then, that at a time when it is becoming clear that public education must focus its attention on thinking skills instruction there exists for the first time enough knowledge about human thought to develop fairly valid thinking skills models.

The task, then, seems well mapped -- direct instruction and reinforcement of thinking skills within public education. But there are many unanswered questions: What are the primary thinking skills? How do they relate to what is currently being taught in the schools? To what extent are they reflected in standard testing procedures? In this paper we will address these and other issues. However, the primary intent of the paper is to describe a model of thinking skills instruction developed from a unitary theory of cognition. Prior to describing that model we will briefly consider some of the currently used models for thinking skills instruction.

THINKING SKILLS MODELS

Although not originally intended as a framework for teaching thinking skills, Bloom's (1956) taxonomy of educational objectives (cognitive domain) is perhaps the most widely used model for reinforcing thinking within the public schools. The taxonomy (as it has come to be known) includes six levels: 1) knowledge, 2) comprehension, 3) application, 4) analysis, 5) synthesis and 6) evaluation. Bloom's model has some intuitive appeal. The principle value of the taxonomy has been its impact on educational measures, specifically teacher made tests (Hopkins & Stanley, 1984): "A teacher who has been exposed to the taxonomy, with illustrations of how higher mental processes can be measured (often objectively), can no longer be satisfied with a test that measures only rote learning of isolated facts" (p. 174). The main shortcoming of the taxonomy is its lack of specificity (Marzano, 1984c). That is, Bloom does not adequately describe the constructs used to define the six levels of processing. For example, consider Bloom's description of knowledge -- the first level of the taxonomy: "...the recall of specifics and universals...methods and processes or a pattern, structure or setting." Without an operational definition of such constructs as specifics, universals, methods, etc. Bloom's definition of knowledge is limited as an educational tool. It is perhaps this lack of specificity that accounts for the confusion among educators about levels of the taxonomy. Several investigators (Mc Guire, 1983; Kropp et al., 1966; Stanley and Bolton, 1957) report that judges frequently disagree on the taxonomy level of test items and classroom questions. Indeed, among the higher levels of the taxonomy agreement is the exception rather than the rule (Poole, 1972; Fairbrother, 1975; Wood, 1977). Bloom's taxonomy can be considered an early attempt to develop a list of general or generic thinking skills, by gathering educators together and, from an intuitive perspective, generating categories of thinking. This is similar to the recent effort of the College Board (1983).

A few of the current models are derived from theories of intelligence. In this category the most widely used model is Meeker's (1969) which is based on the work of Guilford (1967). The Structure of Intelligence model (SOI) assumes that intelligence consists of 120 thinking abilities which are combinations of operations (eg. remembering, analyzing), content (eg. words, symbols) and products (eg. groups, relationships). Still in a beginning phase are the efforts to translate Sternberg's (1984) triarchic model of intelligence into instructional techniques.

Some thinking skills programs use a single skill or ability as the focal point for all instruction. For example, de Bono, (1983) uses "lateral thinking" as the hub of his instructional program. Whimbey (1984) uses "precise processing." Many thinking skills programs emphasize critical thinking (Paul, 1984). Still others stress "creative thinking" (Perkins, 1984).

Some thinking skills models take what might be called a developmental approach. According to Nickerson (1984) a Piagetian emphasis is evident in some programs because they lead students from the more specific and concrete to the more general and abstract. Examples of such programs are the Cognitive Matching Levels project (Brooks et al., 1983) and Accent on the Development of Abstract Processes of Thought (Campbell et al, 1980).

Heuristic models emphasize the teaching of processes or how to do things. A heuristic is roughly synonymous with a strategy. In general a strategy is the idea of an individual about the best way to act in order to accomplish a goal (van Dijk and Kintsch, 1983, p. 65). Most heuristic models are limited to problem solving activities. Polya (1957) was one of the first modern day mathematicians to develop a heuristic for problem solving. More recently problem solving heuristics have been proposed by Wickelgren (1974), Reif and Heller (1982) and Hughes (1979). Another type of instructional system that falls within the general category of heuristic programs is the learning strategies emphasis within the general field of learning disabilities. Most noteworthy here are the programs developed by Alley and Deshler (1979).

An approach to thinking skills instruction that is relatively distinct from the other general categories presented here is the philosophical approach. Most prominent in this category is the Philosophy for Children program developed at Montclair State University (Lipman et al., 1980; Lipman, 1984). The thrust of philosophical programs is to help students become aware of themselves as thinking beings. According to Nickerson (1984) they assume that children have a natural curiosity about the world, about themselves and about their minds and how they work.

A final category of thinking skills programs is the eclectic class of models. Such programs have the same general intent as the generic models (eg. Bloom and the College Board) however, their developmental methodology is different. Where the generic models poll educators the eclectic models attempt to organize those thinking skills found within research and theory in cognition. They do not begin with a model of cognition; rather with a set of predefined cognitive skills that are then categorized. An example of an eclectic approach is Project Intelligence (reported in Nickerson, 1984) which has over 80 different skill areas combined into six major categories: (1) foundations of reasoning, (2) understanding and language, (3) verbal reasoning, (4) problem solving, (5) decision making and (6) inventive thinking. Another example is Feuerstein's Instructional Enrichment program (Feurestein et al., 1980) which has nine basic categories of thinking skills: (1) classifications and comparison, (2) orientations in space, (3) recognizing relationships, (4) following directions, (5) planning (6) organizing, (7) logical reasoning, (8) inductive and deductive reasoning and (9) synthesizing.

ASSUMPTIONS UNDERLYING THE PROPOSED MODEL

In their present state most of the models described above are based on some set of assumptions about cognition, learning, teaching or all three. The model presented in this paper was developed with four assumptions in mind:

1) An instructional model of thinking skills must be compatible with a generalized theory of cognitive behavior.

2) An instructional model of thinking skills must fit into the existing curriculum of public education.

3) Thinking skills must be taught explicitly to students by name.

4) Thinking skills must be tested explicitly.

Sternberg (1983) has suggested a number of criteria for thinking skills training programs. His first criterion is that training models should be based on sound cognitive theory. This is essentially the same as the first assumption listed above. The intelligence based models described in the previous section attempt to define thinking skills using a theory of intelligence as defined by intelligence tests. However, it has recently been found that intelligence tests do not consider many skills and abilities commonly used in daily life (Sternberg, 1984). For the model presented here an attempt was made to identify a generalized theory of cognition and human behavior within which thinking skills could be identified. The general model selected was the unitary theory of cognition as described by Anderson (1983): "The most deeply rooted preconceptions guiding my theorizing is a belief in the unity of human cognition, that all higher cognitive processes, such as memory, language, problem solving, imagery, deduction and induction are different manifestations of the same underlying systems." (p.1) It should be noted here that this position is not universally held among theorists in cognition. Anderson cites Chomsky (1980) as one of the major spokesman for the pluralistic view of mental abilities: "...there seems little reason to insist that the brain is unique in the biological world, in that it is unstructured and undifferentiated, developing on the basis of uniform principles of growth or learning -- say those of some learning theory or some yet-to-be conceived general-purpose learning strategy -- that are common to all domains." Recent years have seen a popularization of the pluralistic view of mental abilities. For example, Gardner (1983) posits at least seven different types of intelligence. In a similar vein the educational interpretation of brain laterization research (eg. Hart, 1983: Zdenek, 1983) and the learning styles movement within education (eg. Kolb et al., 1974; Gregoric, 1979; Letteri 1982; Dunn and Dunn, 1978) have added to the popular belief that cognitive abilities are distinct, independent constructs.

This author takes the stand along with Anderson (1983) and many others who have developed generalized models for such constructs as problem solving (Newell and Simon, 1972), inference (Lehnert, 1978) and general schema systems (Bobrow & Winograd, 1977; Minsky, 1975; Schank and Abelson, 1977) that mental systems can be described in a unitary fashion. This is not to imply that individuals can not and do not drastically differ in their abilities to perform different tasks and even in their style of performing tasks. It simply means that there is an underlying "sameness" about all tasks. As Anderson (1983) says: "This is not to deny that there are many powerful special-purpose "peripheral" systems ... However, behind these lies a common cognitive system for higher-level processing." (p.1)

The second assumption underlying the development of the model asserts that thinking skills instruction must fit into the existing curriculum of public education. Specifically, by curriculum here is meant the content taught in subject area classes. According to the Beginning Teacher Evaluation study (Fisher et al., 1978) and supporting studies (Borg, 1980; Rosenshine, 1980), the curriculum of early elementary grades reflects an emphasis on fundamental operations in reading and mathematics (the so-called basic skills). Students also receive information about social studies, music, nutrition, art, and physical fitness. As students progress through the grades the emphasis shifts to such traditionally academic areas as algebra, history, biology, and literature (Doyle, 1983). The "job" of teaching as seen by teachers is to quickly move students through the basic skills so that they can master the "content" of the higher grades. Assumption #2 of this model asserts that any thinking skills program that does not fit within regular classroom instruction (eg. de Bono, 1983) and does not improve students' knowledge of content will inevitably fail within public education. A relevant question here is what is "content". Academic content has been defined as domain--specific knowledge. Domain specific knowledge "consist of a well-formed semantic network of valid information in an academic area but also of strategies for using this information" (Doyle, 1983, p. 168). In more teacher oriented language content is comprised of "facts" about a specific area and "strategies" for using those facts. This general breakdown of content into two broad areas is suggested by the research of Resnick and Ford (1981), Larkin (1981) and Chi et al., (1981).

The third assumption of the model is that thinking skills should be explicitly taught and labelled. This is to say that it is not enough to simply provide tasks which reinforce thinking skills. Rather they must be differentiated as specific activities and explicitly taught to students. It is true that tasks in themselves can provide students with information and an understanding of operations relative to those tasks (Frase, 1972). For example, Doyle (1983) states that accomplishing a task has two consequences: "First a person will acquire information--facts, concepts, principles, solutions--involved in the particular task that is accomplished. Second, a person will practice operations--memorizing, classifying, inferring, analyzing

--used to obtain or produce the information demanded by the task" (p. 162). However, there is evidence to show that unless explicitly taught many students--particularly those from the lower socio-ecomonic status backgrounds -- will be unable to transfer the operations and information to other situations (Becker, 1977). For example, Beyer (1984) identifies insufficient proceduralization as a major problem in learning. He advises teachers to provide step by step instruction on how to use specific thinking skills.

There is also a more philosophical validation of the need to define and label specific thinking skills. The act of labeling a phenomenon actually brings into existence distinctions that were not evident prior to the creation of the label. Condon (1966) states that naming phenomena has two consequences. First, we begin to notice those things for which we have created the name. The second consequence is that we begin not to notice certain things. For example, prior to taking a course in astronomy we might look up at the night sky and see a sea of lights. After taking the course we no longer can see the sky in the same way; rather we see super novae, white dwarfs, galaxies. As Condon says: "For better or for worse, when names are learned we see what we had not seen, for we know what to look for." (p. 31)

The final assumption underlying the model is that thinking skills must be explicitly tested. About this issue Doyle (1983) states that accountability drives the academic tasks presented to students. As a result students are especially sensitive to cues that signal accountability. Students tend to take seriously only those tasks for which they are held accountable (Carter & Doyle, 1982; King, 1980; Winne and Marx, 1982). Given the complexity of most higher level cognitive processes, many teachers avoid evaluation of higher level thinking skills and indirectly transmit the message that they are not important. It is for this reason that Doyle (1983) comments: "The central point is that the type of tasks which cognitive psychology suggests will have the greatest long-term consequences for improving the quality of academic work are precisely those which are the most difficult to install in classrooms." (p. 180)

The remainder of this paper will outline an instructional model of thinking skills built on these four assumptions . We begin with a discussion of the unitary theory of cognition.

THINKING AS A UNITARY PROCESS

As mentioned previously, the theory of cognition used to develop the thinking skills instructional model was that developed by Anderson (1983). In an effort to translate Anderson's work into an educationally usable format, some of his terminology has been changed. Anderson posits that information in working memory is channeled into either declarative or production memory. Working memory is roughly akin to what is commonly referred to as short term memory (Norman, 1965). Declarative memory is comprised of information in "chunks" or cognitive units. These organizational structures are probably arranged in a hierarchical format like that first suggested by Ausubel (1963). In non-technical terms declarative knowledge is comprised of the "facts" we know about a particular topic. For example, assume an individual knows about the general area of statistics. His/her knowledge about statistics would include such information as: 1) the characteristics of specific concepts (eg. mean, standard deviation);

2) generalizations about various principles of statistics; 3) comparative information about various concepts and principles.

Production memory contains information about how to accomplish tasks using declarative information. For example, the individual who knows the declarative knowledge about statistics would also know how to use that knowledge to do such things as calculate a mean and determine the correlation between two sets of data. Anderson's two primary types of knowledge structures, then, (declarative and production memory) are quite compatible with the way content is defined within education. (Recall that domain specific or content knowledge is comprised of a well-formed semantic network of information in an academic area and of strategies for using that information). Given this inherent compatibility between Anderson's model and the structure of educational content it would seem that a thoughtful interpretation of Anderson's model would shed light on our understanding of academic content.

From Anderson's model we might infer that the driving force behind cognition (and, perhaps, human behavior in general) is the information in production memory. Production memory contains productions. In general, productions are deductive or inductive inference systems that use patterns or rules to guide decision making (Newell and Simon, 1972; Waterman and Hayes-Roth, 1978). According to van Dijk and Kintsch (1983) productions are best described as antecedent--consequent pairs. The antecedent of the rule is matched to some input condition (the information in working memory) and the match results in the execution of some consequent action. Productions can be traced to the early work of Post (1943). To illustrate a production consider the following example suggested by Anderson (1983, p. 6.)

IF: person 1 is the father of person 2 and person 2 is the father of person 3

THEN: person 1 is the grandfather of person 3

"Production systems" are networks of productions. For example, Anderson describes a production system for doing two column addition which is comprised of twelve integrated productions. Production systems can be highly complex structures such as designs (Perkins 1984) and plans (de Beaugrande, 1980).

As described thusfar Anderson's model asserts that at any point in time an individual has a number of production systems that can potentially be activated. That is, the "if" or "antecedent" parts of the production systems are in a ready state--looking for matching information. If matching information is received in working memory the production system is activated. To use a simplistic example, assume that an individual has a production which might be stated in the following way:

IF: 1) it is snowing and
2) the time is before 9:00 a.m. and
3) the snow accumulation is more than three inches;

THEN: I must shovel the driveway.

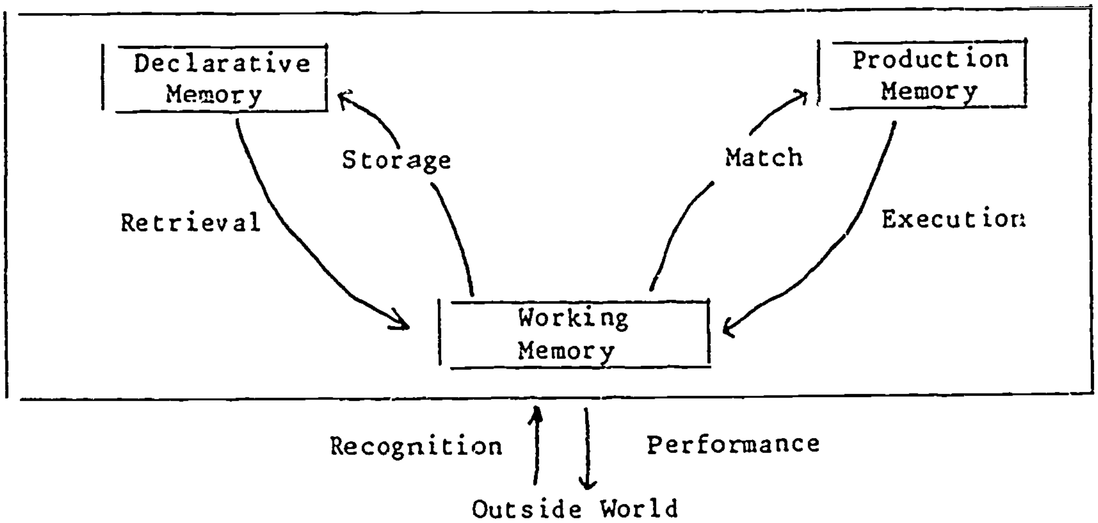
If the individual wakes in the morning and finds antecedent conditions 1, 2, and 3 met, then s/he will engage in the consequent action--shoveling the driveway. This view of human behavior is quite consistent with the cybernetic model postulated by Powers (1973) and then popularized by Glasser (1981). Glasser calls the antecedent conditions in their ready state "comparison stations." Input information (that in working memory) is constantly being referenced to the comparison stations we are currently controlling for (those stations that have the highest potential for a match with the input information). When input information matches a comparison station we "act" on that information or in Anderson's terminology a production system is executed.

We might infer from this model that for an action to be initiated by a human being, the individual must posses a production or production system for the action and the antecedent condition or conditions for the production system must be present in working memory. In a similar vein for a production or production system to exist an individual must have the declarative knowledge of which the productions are comprised. To illustrate using the first example of a production, if an individual did not have the concept <u>father</u>, then the production could not exist. This illustrates the symbiotic relationship between declarative and production memory. Production memory is built from declarative memory; without the "facts" about a particular content area few productions can be constructed. This assertion is consistent with the research findings of Heller and Reif (1984), Larkin (1981) and Anderson (1982)--namely that without the factual knowledge relative to a content area students have little success in acquiring the more complex procedures for the content.

Two relevant questions here are: 1) What are the different types of productions? and 2) How do they interact with declarative memory? To answer these we should consider Anderson's (1983) model in more depth. Figure 1 contains an adaption of Anderson's conceptualization of the basic cognitive processes and their interactions:

Figure 1

Adaptation of Anderson's Model



According to this model there are two basic types of processes an individual is constantly engaged in: 1) recognizing the outside world and 2) reacting to what s/he has recognized. A useful metaphor is to say that an individual is continually asking and answering the questions "What is it?" and "What should I do about it?" for the information in short term memory. Anderson describes the entire system as the interaction of five fundamental processes: 1) encoding, 2) storage, 3) retrieval, 4) matching and 5) execution. "The encoding process deposits representations of the environment into working memory. The storage process deposits permanent records of temporary working-memory information into declarative memory. The retrieval process brings these records back into working memory. The match process selects productions to apply according to the contents of working memory. Finally, the execution process creates new working memory structures through production systems." (p. 47). We might say that these represent five fundamental types of production systems or cognitive tasks--five processes in which an individual is constantly engaging.

What the model as described thusfar does not address is how attention is turned to any one set of productions. That is, given that an individual has perhaps thousands of possible productions which can be activated how does one select which productions to set to a "ready state?" To use Glasser's (1981) terminology, how does one select comparison stations for which to control?

Some classic experiments in psychology (Norman, 1969) indicate that an individual can hold only a few elements in working memory at any one time. Given this, there must be some selection among the many stimuli bombarding an individual at any one time. This selection of stimuli is called "attention." Luria (1973) distinguishes between two basic types of attention: 1) automatic and 2) voluntary. The first type is akin to what Pavlov called the "orienting reflex" (Luria, 1973, p. 250). Automatic attention occurs when some novel situation enters into the individual's awareness. For example, if a young child hears a loud noise, s/he will turn the eyes and head toward the noise. Voluntary attention occurs when an individual shifts the general "background" of attention. For example, while driving at night you might voluntarily turn your attention to the stars. At that point a new set of productions is set to a ready state. You begin to notice things about the sky of which you were previously unaware. To account for this shift in general background, Sternberg (1983) has hypothesized the existence of another type of memory structure called "executive memory". Executive memory contains what Sternberg called meta-components. Useful for understanding meta-components is Newell et al's (1963) concept of a heuristic--not an exact procedure or production;

rather a general rule adherence to which tends to make programs run more smoothly. Powers (1973) refers to such controlling structures as principles.

The heuristics or principles in executive memory, then, control voluntary attention. When we shift attention voluntarily we activate new production systems to a ready state and de-activate others.

The amount of productions which are in a ready state can be narrowed by setting a goal. Anderson (1983) makes the distinction between data driven and goal driven behaviors. When a goal is artificially introduced into the system those productions that relate specifically to the goal are given a high state of readiness--a high potential for activation. The potential of other productions is dampened. Goal setting creates a state of focused attention similar to that described by Neisser (1967) as a controlled state (vs. preattentive) by Lindsay and Norman (1977) as a conceptually driven state (vs. a data driven state) and by Posner (1978) as a conscious state (vs. an automatic pathway activation state).

One final question to consider with the unitary model of cognition is what happens when an individual activates a production system that is not well developed or has to "piece together" a new production system to accomplish a goal? For example, assume an individual sets as a goal to acquire a million dollars and has never done so before--the individual has no productions which directly fit the goal. Intuitively we would guess that in addition to all of the processes described thusfar the individual would engage in a good deal of self-evaluation or have a great deal of self-doubt relative to the goal. This notion is consistent with Rigney's (1980) assertion that a learner is continually seeking answers to six questions: 1) What is it?, 2) What should I do about it?, 3) How can I do it?, 4) Can I do it?, 5) How am I doing it? and 6) Am I through? According to Wagner and Sternberg (1984) these questions are asked automatically for all tasks. As they relate to the unitary model presented here question #1 is analogous to the encoding process. Questions #2 and #3 relate to the selection of an appropriate production system. Questions #5 and #6 deal with the monitoring of the production via principles or heuristics in executive memory. Question #4 introduces a new component into the unitary model of cognition--the individual's monitoring of his/her ability to accomplish the goal. Within education this process is generally studied in the literature on self-concept. Current research has shown that self-concept is multi-faceted with many sub-areas (Shavelson and Bolus, 1982; Shavelson et al 1976). More specifically self-concept can be considered as somewhat task specific. An individual may have a positive self-concept relative to his/her ability to accomplish one task and a negative self-concept relative to his/her ability to accomplish another task. Marsh et al. (1983) assert that self-concept is descriptive and evaluative relative to the accomplishment of a goal. If an individual feels s/he can not perform a task this adds considerable "noise" to the system and processing can not continue at an efficient and automatic level (La Berge and Samuels, 1974).

We now have a fairly comprehensive unitary model of cognition. At any point in time an individual is selecting the stimuli to attend to based on control from executive memory. Information received in working memory is compared to reference conditions or the antecedent components of production systems. An individual can narrow the possible number of production system which can be activated by setting a goal. There are five basic types of production systems or mental procedures which can be activated. They are 1) encoding procedures, 2) storage procedures, 3) retrieval procedures, 4) matching procedures and 5) executive procedures. These processes utilize and add to the information in declarative and production memory. When a production is activated the individual monitors his/her ability to efficiently complete the production. If the individual concludes that there is a high potential for noncompletion, interference or noise is added to the system which decreases the efficiency of the production. As the production is being executed the individual monitors the activity for efficiency and for completion.

Given the overall goal of this paper the task now is to translate this unitary model of cognition into an instructional model of thinking skills.

AN INSTRUCTIONAL MODEL

This section will attempt to translate the unitary model of cognition into procedures or "thinking skills" which can be taught and reinforced in content area classrooms. The reader should note that the terms procedures, processes, productions and thinking skills are used interchangeably. We will consider six general categories of thinking skills: 1) a general procedure for increasing task efficiency; 2) recognition and encoding procedures; 3) storage and retrieval procedures; 4) matching procedures; 5) procedures for building new cognitive structures, and 6) executive system principles. The first general category is an attempt to translate the unitary model into a generic procedure which can be used for all tasks--academic or otherwise. The remaining five categories include the basic cognitive processes suggested by Anderson (1983) (note that storage and retrieval are combined into one category) and the executive principles suggested by Sternberg (1983) and others. Before discussing those categories two points should be made.

First, any attempt to transform a model of cognition into instructional pedagogy is at best a rough translation. Most cognitive models (particularly the one used here) describe cognitive processes at the micro level--a detailed, linear analysis of the process or production being studied. For example, Anderson's model was developed for a computer simulation program called ACT, Adaptive Control of Thought. Clearly, instruction in thinking skills can not occur at the level of specificity used to develop a computer program which simulates human thinking. Hence, the procedures or "thinking skills" identified within the six categories are more macro-processes. In general all of the process identified within a category have the same basic goal (eg. storage and retrieval, matching information); however, because they are macro-processes there is some overlap of categories. That is, processes in one category might share characteristics with processes in another category.

Secondly, the identification of specific processes to be taught as thinking skills should not be misconstrued as an assertion that students should be taught the processes in a prescriptive manner. The ultimate goal when teaching thinking skills is to make students aware of the underlying processes in a meta-cognitive sense. Recent research indicates that a characteristic of individuals who have a relatively high level of mastery over a process is a meta-cognitive knowledge of the process (Meyers & Paris; 1978; Resnick 1983). This creation of a "mindfulness" about the procedure for accomplishing a task appears to be a high level of control (Sternberg, 1983) and a characteristic of what is sometimes referred to as fluid intelligence (Cattell & Horn, 1978; Snow, 1982). There is even evidence that students when taught an inefficient algorithm for a task will transform it into an efficient one over time (Groen & Resnick, 1977). A useful way of interpreting the emphasis in this paper on teaching students procedures for thinking skills is that the intent is to create a common "language of cognition" between students and teachers with which they may both explore and develop higher cognitive processes.

<u>A General Procedure for Increasing Task Efficiency</u>

The unitary model of cognition as described above can be translated into a process for increasing the efficiency of any task. That process might be stated as:

1. Before performing a task clear your mind of unrelated thoughts as much as possible.
2. Set a goal and focus your attention on that goal.
3. Note your self talk relative to your ability to accomplish the goal. If that self talk is negative replace it with more positive statements.
4. Engage in the task.
5. Monitor your activity to determine if the goal has been completed.

The intent of step #1 is to make students aware of their role in the voluntary selection of the general background of stimuli to which they attend. In more educationally oriented terms step #1 makes students aware of their responsibility to attend. Step #2 narrows attention to the specific productions which can be used to accomplish the goal. Step #3 makes students awate of any negative self-talk that might interfere with the task and attempt to override it with more positive messages. Steps #4 and #5 help students cultivate a sense of task completion and transition from one activity to another.

There is no research done on the effect of this specific procedure. However, components of it have been tested within education and general models such as this are fairly common within business training (eg Tiece, 1976). Step #1 of the process has been studied within the general area of attention training. Goodman (1974) working with small children who exhibited a high level of impulsivity--inability to focus attention on a single stimuli--found that they could be trained to attend more directly for a longer period of time. Similarly Egeland (1974) observed that attention training increased student reading performance. On the other hand some researchers have found little or no relationship between attention training and achievement. (Albert, 1970; Nelson, 1968) although their findings were primarily with highly impulsive children.

Relative to step #2 (setting a goal) Sears (1940) found that successful students tended to set explicit goals about classroom activities. Byers (1958) found that students could be taught goal setting behavior and that this training had a positive effect on achievement. Although not based on a study of students, it is interesting to note that Peters and Waterman (1982) found that a common attribute of successful businesspeople is goal setting behavior.

The third step in the process--the monitoring of self-talk has received a great deal of attention within the general field of cognitive restructuring. Cognitive restructuring refers to a variety of techniques used to change an individual's self-statements as well as the premises, assumptions and beliefs underlying these self-statements (Meichenbaum, 1977). Two of the more commonly used tools for cognitive restructuring are verbal mediation and affirmations. Verbal mediation is the use of language as an internal regulator and tool for thought (Camp and Bash, 1981). In its simplist form, verbal mediation is talking to oneself to facilitate the accomplishing of a goal (Jensen, 1966, Meichenbaum, 1977). Apparently the very act of "languaging" one's thoughts makes them more salient and manageable. Luria (1961) and Vygotsky (1962) describe a developmental sequence in this ability and Jensen (1966) states that it is the biggest difference between humans and apes. In the general model described above verbal mediation is intended to be used to make students aware of their internal self-dialogue relative to a task much in the same fashion suggested by Camp and Bash (1981) and by Ericsson and Simon(1979).

Affirmations are overt statements made by students to create a positive self-evaluation relative to a goal. Harmon (1982) has found that affirmations can be taught to students for general as well as specific goals. Again, affirmations are more commonly used in business training than in education (Tiece, 1976).

Steps 4 and 5 in the process have been suggested as efficient devises for providing students with a sense of task closure and completion (Hunter and Breit, 1976). These steps are also consistent with

Hymen and Cohen's (1979) suggestion that instruction should be broken down into distinct, digestible "bites" for students.

Recognition and Encoding Procedures

The overall goal of recognition and encoding procedures is for students to identify and integrate information in short term memory with information in long term memory. These procedures have their primary impact on declarative knowledge--a student's understanding of the "facts" relative to a content area. In this section we will consider some basic recognition and encoding procedures. Before describing these processes we should first elaborate on the previous discussion of declarative memory.

Recall that declarative memory contains hierachially arranged facts or chunks of information. The basic unit of declarative information is probably the concept. Concepts are elementary particles of thought. Klausmeier and Sipple (1980) state that "concepts provide much of the basic mental materials for thinking. They enable the individual to interpret the physical and social world and to make appropriate responses. Without concepts with which to think, human beings like lower form animals would be limited mainly to dealing with sensorimotor perceptual representations of reality that are closely tied to immediate sensory experience" (p. 4).

Within education the term "concept" is widely misused to represent a variety of constructs. Here it is used in a fairly technically rigorous way. A concept is the "socially accepted meaning of one or more words which express the concept" (Klausmeier and Sipple, 1980, p. 78). For example, the word dog is a label society uses to represent the conceptualization of a set of four-legged animals with certain characteristics. We might say that vocabulary knowledge is the isomorphism between an individual's store of concepts and the labels society uses to represent those concepts. It is no wonder, then, that vocabulary knowledge has been cited as the strongest predictor of general academic ability. For example, Anderson and Freebody (1981) report that the strong relationship between vocabulary and general intelligence is one of the most robust findings in the history of intelligence testing.

A level up from the concept as a unit of information in declarative memory is the proposition. Roughly speaking, propositions are "conceptual structures that are the minimal bearers of truth or satisfaction. Thus, 'John' is a concept but is not information that can be true or false...whereas 'John is ill' would be a proposition because it could be true or false" (van Dijk, 1980, p. 207). Propositions, then, are sets of concepts which together make up information that can be true or false/satisfied or dissatisfied in nature.

There is ample research evidence to show the primacy of proposition recognition in information processing. For example, Bransford and Franks (1971) found that comprehension was best characterized as a process of synthesizing information into semantic chunks that are propositional in nature. Sach (1967) found that while memory for specific aspects of a sentence faded quickly, the memory for the propositional gist of a sentence was remarkably stable. Working with children, Pearson (1974-75) obtained results corroborating the findings of Bransford and Franks, and Sachs. Propositions are so basic to the processing of information that we might say that a proposition is a good operational definition of an idea.

Propositions are linked to one another by what might be called "relationships." To illustrate, consider the following:

Bill is tall but.....
he doesn't play basketball.

Here there are two propositions: 1) "Bill is tall" and, 2) "he does not play basketball." These propositions are connected via a relationship signaled by the linguistic connective "but." When recognizing linguistic information in short term memory, a primary step is the identification of these referential links or ties between propositions (Kintsch and van Dijk, 1978; Meyer, 1975; Waters, 1978; Kintsch 1979).

Above the level of identifying relationships between propositions is the organization of proposition into larger chunks or patterns (Schank et al., 1975; de Beaugrande, 1980). There are many different theories as to the organizational structure of these chunks. Marzano (1983b) has identified five basic macro-patterns used to organize information; various macro-structures have been identified by Kintsch and van Dijk (1978); van Dijk (1980) has identified facts and super-structures as organizational units, and a number of theorists have described various structures for schemata (Rumelhart, 1975; Mandler and Johnson, 1977; Stein and Glenn, 1979).

We might say, then, that recognizing and encoding information involves the identification of structures ranging from concepts to large organization patterns. There are five thinking skills or procedures which facilitate the encoding and recognition of information. They are: 1) concept attainment, 2) relationship identification, 3) pattern recognition, 4) reading and 5) listening.

1) Concept Attainment

Given the strong relationship between concept attainment, vocabulary development and academic achievement it seems evident that an instructional system which increases a student's vocabulary would concurrently expand his/her concept knowledge and have an effect on achievement. Indeed, it was Becker's (1977) recommendation after a thorough analysis of the research on various interventions for educationally disadvantaged students that systematic vocabulary instruction in the basic concepts as defined by Dupuy (1974) should be a high educational priority. Relative to this issue a useful question is how are concepts attained. Klausmeier and Goodwin (1971) list eight activities that should be part of the concept attainment process.

1. To get a definition of the concept that states its defining attributes.

2. To identify the defining attributes of the concept and also some of its irrelevant attributes.

3. To identify examples and non-examples of the concept that will be used in the instruction.

4. To identify examples and non-examples of the concept that will be used in testing to ascertain whether the concept has been attained.

5. To identify the taxonomy of which the concept is a part and to indicate the supraordinate-coordinate-subordinate relations of the particular concept to other concepts.

6. To identify some of the principles in which the concept is used.

7. To identify kinds of problems whose solution will involve use of the concept, a principle, or both.

8. To identify the names of the attributes of the concept. (p. 286)

A broader view of concept knowledge is that a concept is the linguistic label for a set of experiences. For example, Underwood (1969) identifies nine attributes associated with an experience. These include such characteristics as images, sensory information, affective information and semantic attributes (eg. time, place, general context). Based on this model, knowing a concept would be defined as having a label attached to a certain set of memories. A concept within Underwood's model, then, would be much more loosely defined than in Klausmeier and Sipple's model. A way of reconciling the two positions is to make a distinction between concept attainment and concept development. Concept attainment might be operationally defined as the creation of a label for a set of experiences as defined by Underwood. Concept development would be operationally defined as making the distinction among concepts that would be necessary to perform the activities suggested by Klausmeier and Goodwin (1971). The <u>concept attainment</u> process then would be the association of visual, sensory, affective etc. information with a commonly accepted label (word) for those experiences. The <u>concept development</u> process would be that described by Klausmeier and Goodwin.

<u>2. Relationship Identification</u>

The way an individual recognizes relationships between propositions is by looking for various syntactic, semantic and rhetorical signals for those relationships. For example, in the sample sentences used previously the word <u>but</u> was the signal that the two propositions had a contrastive relationship. Marzano (1983a) has identified the signals for

23 different types of relationships between propositions. To illustrate, below are some of the words and phases used to signal what is called an equality relationship:

and, moreover, equally, too, besides, furthermore, likewise, similarly, as well, in addition, besides, like.

The 23 relationships identified by Marzano are similar to those in the systems described by Halliday and Hasan (1976), Meyer (1975), de Beaugrande (1980) and Pitkin (1977). It has been shown that knowledge of these connective devices and what they mean is a significant factor in a student's ability to comprehend information presented in linguistic form (Robertson, 1968). Katz and Brent (1968) found that both first and sixth grade children preferred descriptions of casual relationships that were made explicit by use of a linguistic connective. These findings were corroborated by Marshall and Glock (1978-1979) who found that explicitly stated relationships facilitated the recall of prior information.

Relationship identification in its simplist form might be described in the following way:

1) Identify related propositions
2) Identify the type of relationship
3) Identify the linguistic signal

Instruction relative to relationships between ideas can proceed far beyond the level of simply teaching students to be aware of related ideas. Some very deep levels of abstraction can be discussed and highlighted by considering the underlying meaning signaled by the relationship. For example, consider the following:

She was beautiful but
she was not conceited.

Here there are two propositions joined by what is called a contrastive relationship. The purpose of a contrast relationship is to convey the message that the joined propositions in some way "do not go together." A student's ability to recognize this relationship would indicate one level of awareness. Another level of awareness would be the consideration of why these two propositions "don't go together." That is, the assertion that "being beautiful" does not go with "not being conceited" implies some basic beliefs on the part of the author of these propositions. Questions and discussion which highlight this level of meaning are akin to what Doyle (1983) calls metacomprehension activities.

3. Pattern Recognition

It has been shown that the extent to which higher level patterns or organizational structures of a text are made salient, the easier the information is to process and retrieve (Meyer, 1975; Kintsch, 1974; Frederiksen, 1979). Unfortunately, many texts are not written in a format that makes these patterns obvious. It has been strongly suggested (Pearson, 1981) that texts be written in more explicit patterns and that patterns be directly taught so as to facilitate comprehension.

In general, the only exposure students have to patterns is in the area of writing instruction; here students are commonly taught paradigms for writing (D'Angelo, 1980). Unfortunately, there is very little transfer of use of these paradigms to situations outside writing. Specifically, I am recommending that students be taught to recognize patterns within information they read or hear. Here the term pattern includes most of those higher level structures mentioned previously (eg. macro-patterns, super-structures). This was the gist of the recommendations made by Anderson (1978) in his discussion of learning strategies. There is a rapidly growing body of research which indicates that patterns can be explicitly taught and used by students to facilitate the processing and retrieval of linguistic information (Taylor and Samuels, 1983; Alexander et al., 1983; Leslie and Jett-Simpson, 1983; Greenewald and Pederson, 1983). That is, overt instruction in pattern recognition appears to improve processing of information.

We might operationally define the pattern recognition process as follows:

1. Identify patterns in information read and heard.
2. Arrange the patterns relative to which include the most information and/or are most salient

This general process might begin with fairly simple patterns (eg. Marzano's macro-patterns) and proceed to more complex structures (eg. van Dijk's facts)

4 & 5 Reading and Listening

Boyer (1983) in his summary of the Carnegie Foundation study of schools states that language, not science and math, is the foundation for more complex thinking skills. Language is the filter through which we receive the majority of information in school (Marzano, 1984c). It is no wonder, then, that the primacy of language abilities as a factor in school success has been a consistent research finding (Anderson & Freebody, 1981). Indeed, the Russian psychologist Vygotsky (1978) stated that: "the most significant moment in the course of an individual's intellectual development which gives birth to his purely human form of practical and abstract intelligence occurs when speech and practical ability, two previously completely independent lines of development converge" (p. 24). Relative to encoding and recognition procedures reading and listening are the two primary ways students receive information in school. Brown (1980) in a review of literature on meta-cognition found that good readers and listeners have explicit knowledge of the paradigms for these procedures. Theoretical models of the reading and listening processes have been constructed by Kintsch (1979); Kintsch and van Dijk (1978); Goodman (1967) and Olson (1980). Current research has found that overt instruction in adaptations of these models improves students' processing of information while reading and listening (Niles, 1984).

One of the more commonly used reading strategies taught to students is Stauffer's (1980) Directed Reading-Thinking Activity (DRTA). That process includes three phases: 1) predicting, 2) reading and, 3) proving or confirming your predictions. Marzano (1985) has suggested a reading process which includes four steps:

1) Obtain the overall picture of what you are going to read;

2) Look ahead for possible topics within the material;

3) Try to anticipate what will come next;

4) Occasionally stop reading and organize information into patterns.

Listening, although not the same as reading, has many similarities. Sticht et al (1974) has developed a model of listening which asserts that listening: 1) is a process under the voluntary control of the listener, 2) requires selective attention to certain stimuli, 3) requires the integration of new information with old information, 4) involves the generation of hypotheses. Distefano et al (1984) have translated this model into a procedure for listening which includes:

1) Identify the overall type.
2) Determine what you already know about the topic.
3) Make predictions as to what will come next.
4) Ask clarification questions.
5) Organize information into patterns.

Storage and Retrieval Procedures

Storage and retrival procedures increase the efficiency with which information is stored in or retrieved from long term memory. Three basic types of procedures are presented here: 1) reconstruction, 2) deep processing and 3) memory frameworks.

1) Reconstruction

Reconstruction refers to the act of organizing information for storage in long term memory. It is important to note that the term reconstruction is used here in a different way than is commonly found within cognitive psychology. Generally, reconstruction refers to the reorganization of stored information when an individual attempts to recall it. In this paper the term is used to describe the process of inputting new information into long term memory rather than restructuring information already stored. As such it graphically describes the underlying restructuring or reorganizational nature of organizing information for storage. In other words, reconstruction demands that the individual translate the input information into some new meaningful configuration. As described here restructuring is similar to what many educators call "synthesizing."

Van Dijk (1980; 1977) states that there are at least three components to the reconstruction process:

1) generalization: the act of identifying general concepts that subsume more specific concepts stated in the information being processed.

2) deletion: the act of deleting ideas (propositions) that are subsumed under some other stated idea.

3) construction: the act of identifying the normal conditions, consequences or components of stated ideas (propositions).

Van Dijk calls these macro-rules or rules by which an individual creates a macro-structure - the form that is used to store the information.

Translated into an educationally more understandable procedure, these macro-rules can be restated as follows:

1) Identify summary statements.

2) Delete redundant or peripheral information.

3) Construct implied summary statements and/or restate the information in your own words.

2. Deep Processing

Deep processing is the act of creating visual, semantic and sensory associations for information to be retrieved. Visual--imagery mediation (the creation of a strong mental image) appears to be basic to the operation of most memory devices (Bellezza, 1981; Paivio, 1971, 1983). It also appears that people who practice visual imagery mediation become more proficient at it (Bellezza, 1983; Bugelski, 1977).

Semantic associations are those in which the meaning of the information to be processed is expressed linguistically so that it might be stored in auditory memory. This has been shown to be more powerful as a retrieval cue than the processing of acoustic, syntactic or other non-semantic information (Craik and Tulving, 1975; Hyde and Jenkins, 1973). From the discussion of the structure of declarative information in a previous section of this paper it would appear that the identification of patterns of information would provide a strong semantic cue for deep processing. Sensory associations refer to those cues suggested by Underwood (1969). As a procedure, then, deep processing might be described in the following way:

1. Identify the underlying patterns of information to be deeply processed.
2. Create visual images or associations for that information.
3. Create sensory associations for that information.

3. Memory Frameworks

Memory frameworks are used when an individual wishes to recall: 1)sets or groups of information or 2) a linear process or sequence of information. In a metaphorical sense we might liken memory frameworks to the creation of "slots" in which to place information via deep processing. There are a number of memory framework commonly used.

The method of Loci has been found to be very effective in learning lists of information (Ross and Lawrence, 1968). Before using the Loci framework the individual must first memorize the visual image of places such as a series of rooms in a building. When a set or a list of information is to be memorized the individual places each piece of information into a location via deep processing. A similar framework is termed the pegword method. Here the individual invokes as cues visual images of objects rather than location. A common example is the rhyming pegword mnemonic (Miller, et al, 1960) in which the following jingle is first memorized: "One is a bun; two is a shoe; three is a tree; four is a door; five is a hive; six is sticks; seven is heaven; eight is a gate; nine is a line; ten is a hen." An extended version of the pegword method is reported by Lindsay and Norman (1977) in which digits are associated with consonant sounds. These associations are then used to create pegwords for slots which correspond to numerals. Pegword methods have been shown to be successful devices for memorizing small chunks of information like new vocabulary words (Paivio and Desrochers, 1981). However, the intent here is to use memory frameworks for storing larger chunks of information via deep processing. (Recall that the first step in deep processing is to identify the pattern of the information to be memorized.) The procedure for using memory frameworks, then might be described in the following way:

1. Identify the information to be memorized.
2. Organize information into patterns.
3. Select a memory framework.
4. Deposit information in memory framework via deep processing.

Matching Procedures

Matching procedures are those which enable the individual to identify how incoming information is similar to and different from information stored in long term memory. In this section we consider four basic matching procedures: 1) categorization; 2) extrapolation, 3) analogical reasoning and 4) evaluation.

1. Categorization

According to Mervis (1980) categorization is an essential skill because the world consists of an infinite number of discriminably different stimuli. "By categorizing, a person is able to render the unfamiliar familiar, and because one is able to generalize about an object based on knowledge about its category, one is able to know more about the object than just what can be ascertained by looking at it" (p. 279). Although there is debate as to what constitutes a category (Smith & Medin, 1981) and three basic theories of category structure (the classical, probabilistic and exemplar theories), within education reinforcing the skill of categorization is generally accomplished with concepts (Klausmeier, 1976; Markle, 1975). Indeed the process of categorization is very similar to those activities suggested by Klausmeier and Goodwin (1971) for concept development (see previous discussion of "Concept Attainment"). As defined in this model, categorization is meant to be done as a supplement to the concept development process. The procedure might be outlined in the following way:

1. Identify superordinate and subordinate concepts for a given concept.
2. Identify shared attributes within a category of concepts.
3. Identify unique attributes for concepts within a category.

Again, this procedure is meant to be used within the area of concept development. This is quite consistent with the current research on concept/vocabulary learning. For example, Mezynski (1983) in her review of eight vocabulary studies found that the systematic teaching of vocabulary in semantic categories increases vocabulary/

concept knowledge. Key to the reinforcement of categorization, then, within the system described here is the organization of concepts into categories or clusters.

Organizing words into clusters or semantic groups for vocabulary instruction and concept development is not a new educational idea. Such an approach is similar to what is commonly called "mapping" or "webbing." Johnson and Pearson (1978) suggest that clusters of vocabulary items might be drawn from the thesaurus. As effective as this procedure might be in terms of teaching new vocabulary words, it can still be considered a "hit and miss" approach at best in terms of coverage. As Anderson and Freebody (1981) point out, the distribution of word usage is highly unbalanced. That is, relatively few words/concepts constitute a vast majority of the words actually used. For example, of the 86,741 words listed by Carrol, Davies and Richman (1971), over 40 percent of them appear only once within the corpus analyzed. This suggests that there might be a small number of clusters or chunks of concepts which account for most of the vocabulary words commonly used in English. If these basic clusters could be identified, they might be used as a powerful instructional tool.

For this purpose, 7230 words from elementary school textbooks were classified (Marzano, 1984a, 1984b) into three levels or groupings of clusters: 1) super-clusters, 2) clusters, and 3) mini-clusters. Super-clusters are the largest organizational chunks. There are 61 of these. That is, the 7230 vocabulary words were organized into 61 broad semantic categories. Clusters are groups of words with closer semantic ties than super-clusters. There are 430 clusters. We might say that super-clusters are clusters of clusters. Finally, mini-clusters are groups of words with the strongest semantic ties. There are over 1,500 of these.

The super-clusters, cluster and mini-clusters are meant as the framework within which to utilize the categorization procedure described above. This, in turn, aids in the development of concepts/vocabulary.

2. Extrapolation

Extrapolation is the process of matching the pattern(s) of information read or heard with information from a totally different context. Recall that pattern recognition involves the identification of salient patterns in information. Extrapolation would involve matching the pattern(s) of information in one source with the pattern(s) found in another. For example, Marzano (1983b) identifies topic patterns, generalization patterns, sequence patterns and process patterns as useful instructional tools. (Note that these are called macro- patterns rather than patterns). Using this system exprapolation would be defined as:

a) Match the characteristics stated in one topic pattern with characteristics in another.

b) Match the examples of one generalization with the examples of another.

c) Match the sequence of events in one situation with that of another.

d) Match a process in one situation with the process in another.

To illustrate extrapolation, Marzano (1985) gives the example of children reading a description in a basal reader of how to bake bread. Once students have determined that the basic pattern is a "process" they are then requested to "try to identify some other process <u>that is not about cooking</u> which contains some of the same elements as the process for baking bread."

As defined here the dynamics of extrapolation are similar to those of interpreting a metaphor. For example, both metaphor and extrapolation are implicit comparisons (Alston, 1964). Both metaphor and extrapolation have a topic (that pattern being extrapolated to a new context) and a vehicle (that context to which the pattern is being extrapolated). Ortony (1980) states that a cognitive ability such as this develops long after a child has mastered the rudiments of language processing. However, Arter (1976) found that instruction in the use of metaphorical models facilitated the learning of low ability students.

3. Analogical Reasoning

According to Alexander (1984) few intellectual skills are as pervasive or as essential to one's existence as the ability to reason analogically. Broadly defined analogical reasoning occurs when "unfamiliar stimuli are introduced with some reference to the more familiar" (Alexander, p. 192.) In a very broad sense teachers are continually using analogies when they preface a new lesson with a review of known, related knowledge (Hayes and Tierney, 1980; Tierney and Cunningham, 1980; Marr and Gormley, 1982). At a more specific level analogical reasoning refers to a particular type of reasoning problem of the form, A:B :: C:D. According to Sternberg (1977, 1980, 1981, 1982) analogical reasoning contains four components: 1) encoding, 2) inferring, 3) mapping and 4) applying. Encoding is the identification of the attributes or characteristics of the concepts within the analogy. Inferring is the identification of the rule that relates adjacent concepts. For example in the analogy--feather: bird: : leaf: tree the relationship between the adjacent concepts is part to whole. Mapping is the identification of the relationship between non-adjacent terms. For example, in the analogy above feather and leaf both are parts; bird and tree are wholes. Applying refers to identify the missing component in an analogy of the form feather: bird: :_____ tree.

From this model a fairly straight forward procedure can be outlined:

1. Identify characteristics of the elements in the first set and possible relationships between those elements.
2. Identify which element in the first set is most closely related to the element in the second set.
3. Identify what is missing in the second set.

4. Evaluation

Evaluation refers to the procedures for determining the: 1) logic, or 2) value of information. That is, evaluation encompasses two different procedures. The logic of information refers to the extent to which a claim is supported by relevant information. Specifically, Toulmin (1958; Toulmin et al., 1979) has developed a model which implies a specific evaluation of logic process. According to Toulmin's model there are three elements to consider when evaluating the logic of a claim: a) the data used to generate the claim, b) the "warrant" used to support the claim, and c) the "backing" used to support the warrant. Based on this model, a fairly straightforward algorithm can be developed to guide students through the process of evaluating logic:

a) Identify claims in material read or heard.

b) Identify the proof for the claim. If no proof exists, then the claim is unsubstantiated. If unsubstantiated, does the claim fall within the domain of general knowledge?

c) If proof exists, identify any errors in logic.

d) If no error is found, then the claim is substantiated and logical.

This procedure, seeks to match the logic of information presented, with that of some idealized system of logic (eg. Toulmin's).

Evaluation of value refers to the act of determining whether input informtion is considered good, bad or neutral on some internalized scale. The match is between the student's internalized value system and the semantic content of incoming information. The process might be described in the following way:

a) Identify the value you have given to a specific piece of information.

b) Identify the assumptions underlying your assignment of value.

c) Identify another set of assumptions which would render a different value for the information.

Spiro (1980) has stated that this "attitudinal" characteristic of thinking is the central aspect of cognition (p.271). He suggests more research on the order of that by Osgood, et al (1957) and Bransford, et al (1977) to further delineate the defining characteristics of value.

An outcome of the evaluation of value process is that students recognize the subjectivity of their own value systems. This is consistent with Paul's (1984) conception of "dialectic" thinking which he asserts is the primary thinking skill of the future. He states that children "can learn to consider it natural that people differ in their beliefs and points of view and they can learn to grasp this not as a quaint peculiarity of people but as a tool for learning. They can learn how to learn from others, even from their objections, contrary perceptions and differing ways of thinking" (p. 12).

Procedures for Building New Cognitive Structures

The procedures outlined in this section generate new information or drastically restructure the information in long term memory. As mentioned previously, because we are dealing with complex procedures within this model there will naturally be a great deal of overlap among categories of thinking skills. For example, virtually all of the procedures discussed thusfar create some form of restructuring of knowledge or generate new knowledge. However, the procedures discussed in this section are more singular in that purpose than the other procedures within the model. We will consider four basic procedures within this section: 1) elaboration, 2) problem solving, 3) writing and 4) computer programming.

1. Elaboration

Elaboration refers to the inferring of information not explicitly stated. Various categories of inference have been developed by many researchers and theorists. Some theorists posit that an individual will infer the social ramifications of information (Bruce and Schmidt, 1974; Bruce 1975; Schmidt, 1973). Warren et al (1979) distinguishes among three general types of inferences. Here four basic categories of inferences or elaborations are proposed: 1) elaborations about characteristics of concepts, 2) elaborations about causality, 3) elaborations about general background and 4) elaborations about author purpose. The discussions of declarative memory and concept development in previous sections of this paper imply that a major type of information structure in long term memory is attributes or characteristics of concepts. Hull (1920) was one of the first to hypothesize the existence and importance of this type of structure. For educational purpose a characteristic of a concept has been operationally defined (Marzano and Dole, 1985) as states of being, habitual actuals and defining actions for persons places and things. Elaboration of characteristics then, would be the inference of unstated states of being, habitual actuals and defining actions for concepts.

Elaboration of casuality refers to inferring causal relationships between propositions. Johnson--Laird (1983) identifies causation as one of the basic "conceptual primitives that.....build up more complex concepts out of underlying primitives "(p.413). Causality generally occurs between propositions rather than concepts. That is one event generally causes another event rather than one concept causing another. Research indicates that attribution of causality is a natural reaction to all events (Frieze, 1973; Weiner, 1974, 1980). That is, we attempt to infer causes about our own and others' behavior and subsequent attitudes and behaviors (Lavelle and Keogh, 1980). Another form of elaboration, then, is to infer the causes and consequences of stated propositions.

General background refers to van Dijk's (1980) cognitive structure called a "fact." According to van Dijk a fact contains: 1) an event, 2) the participants in the event, 3) the goal of the event, 4) the time and duration of the event and 5) the location of the event. For example, "dinner out' is an event. The participants are usually adults, a waiter or waitress, a cook, etc. The goal of the event is to eat and be entertained. The event takes place in the evening and usually lasts from one to two hours. The location of the event is at a restaurant. A third form of elaboration, then, occurs when an event is selected and the participants, goal, time, duration and location are inferred.

The final type of elaboration is about the author's stance relative to the information being presented. Halliday (1967) calls this theme; Grimes (1972) calls this staging. Here it is referred to as elaboration of author purpose. If one combines the suggestions of Moffett (1983) and Brittan (1970) it can be inferred that there are three primary purposes for communicating: 1) to inform, 2) to persuade and 3) to express affect. Each purpose has specific cues that are used to signal the intent of this information.

Elaboration, then, as defined here has four components. The process might be outlined in the following way:

1. Select a person, place or thing and infer unstated characteristics.
2. Select a proposition and infer unstated causes and consequences.
3. Select an event and infer participants, goal, time, duration and location.
4. Determine whether the purpose of information is to persuade, inform or express affect.

2. Problem Solving

A number of theorists have developed general algorithms for problem solving. For example, Reif and Heller (1982) have developed a general algorithm for solving physics problems: 1) generate an initial problem description and qualitative analysis designed to facilitate the subsequent construction of a problem solution; 2) generate an actual solution by methods which facilitate the decision making required for efficient search, and 3) assess and improve upon the solution. Hughes (1976) has developed a much more simplistic algorithm which includes: 1) understand the problem, 2) devise a plan of attack, 3) carry out the plan, 4) think it over. By far the most commonly cited general problem solving algorithm is that by Polya (1957): 1) understand the problem, 2) devise a plan, 3) carry out the plan, 4) look back. We will consider Polya's algorithm in light of the production system model of cognition presented in this paper.

A beginning place is to define a problem. Unfortunately, few theorists do this. Wickelgren (1974) states that problems contain: 1) givens, 2) operations and 3) goals. Although Polya (1957) offers no explicit definition of a problem, it can be inferred from his description of a general problem solving process that problems involve: 1) given information, 2) unknown operations and 3) a goal to accomplish an outcome which involves the given and unknown elements. Van Dijk and Kintsch (1983) in their proposition based study of problems state simply that problems occur when there is an explicit goal to be reached and there are specific operations, mental steps, to be performed to reach that goal (p. 68).

One thing that appears to be intrinsic to a problem is missing information. For example, if an individual were trying to fix a flat tire but did not know how to do so, the missing information would be the procedure for fixing a flat. To solve the problem the individual would have to create that new knowledge structure (the production system for fixing a flat) for him/herself. Combining the elements of some of the general algorithms mentioned above and the notion of a problem as missing information with Anderson's (1983) theory of cognition we obtain the following general problem solving procedure.

1. Identify the type of procedure involved in the problem (eg. encoding, retrieval, matching, building new structures on executives.)

2. Identify what is missing: Missing data can take the form of:
   a. a missing antecedent in a specific production
   b. a missing consequent in a specific production
   c. a missing production in a production system

3. Decide whether: a) the missing information can be inferred or b) outside information should be obtained. If b, exit the problem solving algorithm and return when information is obtained. If a, ask and answer the question: "In what prior situation have I made a similar inference?"

4. Test out the inference

5. Determine if the inferred missing data completes the production or production system.

3. Writing

The importance of language competence as a fundamental school related cognitive ability (Boyer, 1983; Anderson and Freebody, 1981) was mentioned previously in the discussion of reading and listening as basic recognition and encoding procedures. Nickerson (1984) identifies writing as one if not the key language related procedure for enhancing thinking skills: "writing is viewed not only as a medium of thought but also as a vehicle for developing it." (p. 33) The constructive nature of writing (eg. its generation of new cognitive structures) has been well documented for many years. Many writers report that they begin writing to see how an idea will turn out (Marzano and Distefano, 1981). A number of models of the writing process have been developed (Flower and Hayes, 1981; Nold, 1979; Humes, 1983). Most models include components for planning, recording, reviewing and revising. A procedure which includes all of the commonly identified elements of the composing process and the theory of the structure of information in declarative memory presented in this paper would be stated as follows:

a. Identify what you already know about a topic.

b. Determine if more information is required.

c. When an adequate amount of information is present, begin writing with the intent of simply recording your ideas.

d. Reorganize the information looking for salient patterns.

e. Continue until information is coherently stated.

f. Revise for mechanics.

4. Computer Programming

A popular belief is that the ability to program a computer using current high level languages will create a relatively high level of job marketability for a student. However, this assertion has been strongly challenged. As a marketable skill, computer programming has a dubious future due to the projected technological advances in user friendly hardware and software (Hofeditz, 1984). Yet as a tool for reinforcing thinking skills computer programming may be invaluable, especially for the development of new cognitive structures. Indeed, this assertion was the underlying rationale behind the development of LOGO (Papert 1975; 1980): "In my vision, the child programs the computer and, in doing so, both acquires a sense of mastery over a piece of the most modern and powerful technology and establishes an intimate contact with some of the deepest ideas from sciences from mathematics and from the act of intellectual model building" (Papert, 1980, p. 5). The process of computer programming has been likened to basic problem solving

(Ellis, 1974; Hofmeister, 1984) and writing (Nickerson, 1984), both procedures which create new cognitive structures. More specifically, computer programming appears to involve planning, recording, reviewing and revising phases like the basic writing process. Planning is commonly done quite formally as flow charting. Recording, reviewing and revising are done in a similar fashion to writing with one notable exception--any minute error in logic within a computer program will generally create obvious flaws in the execution of the program. This, of course, is not the case with writing. An individual can have many errors in logic, mechanics etc. and still produce a coherent passage. It is at the level of finding errors in computer logic or "debugging" a program that computer programming becomes analogous to problem solving. In fact, computer commands can be viewed as basic productions. For example, the LOGO command FORWARD can be represented in the following way:

IF: a) screen is set to "turtle" mode
b) and command "FORWARD 4" is entered
c) and execution key is pressed

THEN: turtle will move 4 units in a straight, forward direction from current position and setting

The inappropriate use of a computer command is generally a result of the types of "missing data" identified in the problem solving procedure described in the previous section (eg. missing or unknown antecedent for a command; a missing consequent; a missing command in a set of commands; a missing command in a set of commands within a complex procedure). Hence it is suggested that the process of computer programming be operationally defined as the combination of the writing and problem solving procedures described previously. Students can be taught to program using a variation of the basic writing process and taught to debug their programs using the problem solving procedures.

Executive Principles

According to Sternberg (1984) executive structures are used in planning, monitoring and evaluating one's information processing. Butterfield and Belmont (1977) define executive systems as those which control attention and decision making relative to which productions should be executed at any point in time. Gardner (1983) describes executive systems as those which determine how the organism should deploy its various capacities. What is apparent is that executive systems maintain a high level of control over cognition and behavior in general. Rather than considering executive memory as consisting of productions per se I choose to consider executive memory as composed of high level controlling "principles." Recall that this is consistent with Powers (1973) conceptualization of executive functioning. A principle can be likened to a high level generalization which controls the selection and utilization of procedures. For example, Klasumeier and Sipple (1980) list the following as examples of principles:

1. Making more accurate and reliable scientific observations permits the drawing of more accurate conclusions.
2. Inferences based on two or more scientific observations are more reliable than those based on a single observation.
3. Quantitive observations allow more precision and accuracy in drawing inferences than do qualitative observations.
4. Scientific observing and inferring are essential for predicting the extremes of scientific events. (p. 69)

According to Powers (1973) executive principles are at such a high level of control that they may be unknown at a conscious level to the individual. That is, they may exist at the prelinguistic level alluded to by Flower and Hayes (1984).

Here we will consider three general types of executive principles: 1) principles controlling efficient procedure execution; 2) principles controlling range of behavior and 3) principles controlling range of perceptions.

1. Principles Controlling Efficient Procedure Execution

In a review of the principles used by effective vs. non-effective problem solvers, Whimbey (1980) identified the following as key control features: 1) a faith in persistent systematic analyses of problems; 2) a concern for accuracy; 3) the patience to employ a step-by-step procedure; 4) an avoidance of wild guessing and 5) a determination to become actively involved with the problem. Similar findings have been reported by other researchers and theorists (Sternberg, 1984; Chi, et al., 1982; Larkin, et al., 1981). Here I suggest three principles as fundamental to controlling the efficiency of procedures as they are executed:

1. A willingness to be actively involved in the task.
2. A commitment to persistence and accuracy.
3. A sensitivity to feedback.

The first two principles have been found by Sternberg and Davidson (1982) to be key to generating insights relative to implementing tasks. The third principle (sensitivity to feedback) creates a necessary awareness of the extent to which a procedure is working. Assuming a cybernetic model of behavior, a sensitivity to feedback allows the individual to constantly adjust or correct for errors in the execution of a procedure.

2. Principles Controlling Range of Behavior

Harmon (1982) states that at an unconscious level humans restrain from engaging in behaviors or learnings which would threaten their fundamental beliefs. Abraham Maslow in a paper entitled "On the Need to Know and the Fear of Knowing" (Harmon, 1982) pointed out that humans are culturally taught not to trust themselves or the inherent order of life. In more recent research Harter (1980, 1983) found that a basic trust that content is knowable, problems solvable and life trustable are characteristics of high achievers and, perhaps, a necessary condition for motivation to perform a task. It appears, then, that two controlling principles in executive memory might be:

1. A belief that life is trustable. (That is, circumstances do not automatically work against the accomplishment of a goal; rather circumstances can support the accomplishment of goals)
2. A belief that an individual will generally make decisions supportive of his/her overall well being. (A trust in one's decisions.)

From the research we can conclude that an individual who has these controlling principles would be willing to engage in a wider range of behaviors than an individual who did not have these principles or did have their negative counterparts (e.g. life is not trustable; individual decisions are not trustable). A desire and willingness to engage in many and varied activities has been linked to creativity (Perkins, 1984) and productivity (Fromm, 1968).

3. Principles Controlling Range of Perception

One of the more powerful scientific realizations within the last decade is that perception is fundamentally subjective in nature. That is we perceive only what we expect to perceive. This is most evident in experiments on visual perception (Lindsay and Norman, 1977). Smith (1971) accurately characterizes the subjective nature of human perception:

> What we have in our heads is a theory of what the world is like, a theory that is the basis of all our perceptions and understanding of the world, the root of all learning the source of all hopes and fears, motives and expectancies, reasoning and creativity. And this theory is all we have. If we can make sense of the world at all, it is by interpreting our interactions with the world in the light of our theory. The theory is our shield against bewilderment. (p. 57)

In isolation this is a fairly deterministic view of human cognition. If we can perceive only what we expect to perceive we are tantamount to being stuck in a perceptual "programming loop." However, along with the realization that perception is primarily subjective -- driven by a paradigms which creates perceptual expectations -- is the parallel hypothesis that humans have the power to voluntarily shift paradigms at will given that they are aware of the paradigm from which they are currently perceiving. This concept of voluntary paradigm shifting has affected a wide range of human endeavors from theory and practice in social science research (Skrtic, 1983; Schwartz and Ogilvy, 1979) to economic theory (Henderson 1984-85) to human productivity (Bodek, 1984-85). It would appear, then, that two executive principles which exert a high level of control over procedure execution might be stated in the following way:

1. A belief that perceptions are subjective and are generated from a specific point of view.

2. A belief that one's point of view is controllable and a willingness to change a given point of view.

The existence of both of these principles in creative people has been noted by Golann (1968), Harmon (1982) and alluded to by Johnson-Laird (1983).

Given that not all students possess the executive principles mentioned above there is a need for a procedure to help them understand and acquire them. Harmon (1982) has outlined a process which includes: 1) monitoring of current status relative to the executive principles, 2) systematic affirmation of the principles and 3) use of visualization along with the affirmations. This procedure could be used as a means of introducing and reinforcing the executive principles with students.

Content Specific Procedures

The procedures and principles described, thusfar, account for most of the generalized thinking skills that are educationally pertinent. However, there are no doubt many cognitive procedures specific to content areas. For example Culler (1980) states that there are three key elements to the process of reading poetry.

1. "The rule of significance: read the poem as expressing a significant attitude to some problem concerning man and/or his relation to the universe." (p. 103).

2. "The conventions of metaphoric coherence - that one should attempt through semantic transformations to produce coherence in the levels of both tenor and vehicle." (p. 105).

3. "The contention of thematic entity." (p. 103) by which the reader integrates individual images into the overall image created by the poem.

Culler states that in the absence of this specific knowledge, an individual is almost totally incapable of processing the information presented in a poem:

> Anyone lacking this knowledge, anyone wholly unacquainted with literature and unfamiliar with the conventions by which fictions are read, would, for example, be quite baffled if presented with a poem. His knowledge of the language would enable him to understand phrases and sentences, but he would not know, quite literally, what to make of this literature...because he lacks the complex "literary competence" which enables others to proceed. He has not internalized the "grammar" of literature which would permit him to convert linguistic sequences into literary structures and meanings (p. 102).

Culler's statements highlight the need for content area teachers to identify procedures specific to their content areas and explicitly label and teach those procedures to students.

EDUCATIONAL IMPLICATIONS

The unitary model has many implication for instruction and curriculum. Here we consider four major implications.

The first implications of the model is that academic content should be reorganized into declarative and procedural knowledge relative to specific content areas. More specifically the declarative information within a content area should be subdivided into two basic types: 1) information that can be represented by a concept and 2) information that can be represented by a pattern. The first step in organizing declarative information in this fashion would be to identify basic concepts that run through all content areas and concepts specific to various content areas. As mentioned in the section on categorization Marzano (1984a, 1984b) has identified those core concepts at the elementary level. Becker et al (1980) have identified core concepts in grades K-12. Concepts specific to content areas would be operationally defined as those which are: 1) used only with the content area or are used differently within a content area and 2) used repeatedly in the content area (Marzano, 1985). Relative to the emphasis on concepts as an instructional focus, Becker (1977, p. 539) offers the following suggestions: "By the use of carefully structured programs to boost vocabulary competency for low-performing children in the early grades, the number of children in the lower end of this range can be reduced. By structuring school programs to teach basic operations in the various areas of knowledge using basic words, the advanced children would not necessarily be held back." In effect, Becker is suggesting what used to be called a spiral curriculum (Taba, 1965), using a core of concepts. Differing levels of meaning and interpretation for these concepts would be taught students depending on their familiarity with the concepts.

Other than concepts, content area declarative information would be organized into patterns. For example, social studies events could be organized using van Dijk's (1980) "fact" as an organizational structure. Generalizations with supporting examples and topics with supporting characteristics could be organized using the macro-patterns suggested by Marzano (1983b). Once organized in patterns, declarative information would then be presented to students in their organized states. This presentation of information in structured formats would lessen the cognitive load on students trying to assimilate loosely arranged information in content area textbooks (Pearson, 1981) and in the information presented orally.

The procedural information taught students would consist of the procedures outlined in this model and specific content area procedures identified by teachers. As mentioned previously in this paper, procedures would be explicitly taught by name. Also there would be a mutually supportive relationship between the procedures taught within a content area and the declarative information in the content area; the procedures would help students learn declarative information which, in turn, would help students better understand the procedures.

The second implication of the model concerns testing. As mentioned previously, testing is a strong intervention within the education system. Doyle (1983) asserts that to a great extent it runs the system. That is, elements of the curriculum which are not overtly tested are considered irrelevant by students. This implies that the thinking skills outlined in this paper must be explicitly tested to be considered important by students. Indeed, this is one of the assumption upon which the model was developed. One possibility is that standardized tests, although not specifically designed to test thinking skills, are in fact good measures of thinking skills. This assertion even has some intuitive appeal. However, recent research and theory indicate that standardized tests are not accurate measures of specific skills (Madaus et al., 1980). That is, current standardized multiple choice tests, although similar in surface appearance, require a wide range of abilities to answer different items. Items from a given test are scored together yet no attempt is made to isolate specific skills measured by each item. For example, Wardrop (1970) reviewed standardized reading achievement tests and noted that comprehension subtests differ markedly in content passages presented, lengths of passages, type of behavior required for responding correctly, number of test items per reading passage and readability of the content presented. Wardrop asserts that the operational definition of reading comprehension seems to have become a function of the test author's idiosyncratic feelings about the construct, and in only a few isolated cases have efforts been made to underpin item development with construct theory.

In light of this, it appears that tests specifically designed for measuring thinking skills abilities will have to be developed. There are such tests currently available such as the Cornell Critical Thinking Test (Ennis and Millman, 1982) and the New Jersey Test of Reasoning Skills (Shipman, 1983); however, these are model specific. It also appears that many of the thinking skills defined in this paper and other models do not lend themselves to measurement via multiple choice formats. Given that multiple choice formats are primarily recognition tasks and most of the thinking skills are procedural in nature it would seem that a valid testing of thinking skills would require tasks that are more constructive in nature. To this end Nickerson (1984) recommends the use of writing: "Another major advantage of writing as a means for teaching thinking is that it yields a tangible product that can be evaluated" (p. 33). More specifically essay type tasks could be constructed to evaluate students' use of various thinking skills. Student responses could be scored in a primary trait fashion (Lloyd-Jones, 1977); in this case the primary trait would be the use of specific procedures. Similarly, student protocals (thinking aloud while completing a task) could be analyzed for the existence of specific thinking skills procedures (Swarts, et al., 1984).

A third implication of the model is that diagnosis of student difficulties can be carried out from much more precise and holistic perspectives. Current research on instruction indicates that a teacher's ability to diagnose student strengths and weaknesses is a key component of the teaching/learning process (Berliner, 1984; Hunter, 1984; Denham and Lieberman, 1980). However, most diagnosis is done only within the domain of content and even that is characterized by a lack of knowledge of the procedures and declarative information necessary to perform a task (Doyle, 1983). The model presented here provides a basis from which to develop theory based hypotheses as to the aspect of a task with which a student might be experiencing difficulty (e.g. the student doesn't know the necessary declarative knowledge to complete the task and/or he/she does not have a well developed procedure for completing the task.) The general procedure for increasing task efficiency described early in this paper provides a basis to diagnose more general non-content related reasons for a breakdown in processing (e.g. the student has not focused on the task; the student has no clear goal).

The fourth implication of the model is that elements of what has been commonly called aesthetic education might be more closely linked with the curriculum. There have been many theorists who have strongly advocated the infusion of curricular activities which address some of the basic issues of humanity. The well known "column three" of Adler's Paideia Proposal (1982) is an attempt to enlarge students' understanding of ideas and values by means of Socratic questioning and active participation in the discussion of books. Maxine Greene (1971) has long advocated the need for including consciousness raising activities into the curriculum. Similarly Goodlad's (1983) curriculum suggestions contain elements commonly considered aesthetic in nature. These suggestions, although accepted by some, have had difficulty finding their way into the mainstream of curriculum development. My assertion is that the lack of acceptance for the aesthetic movement is due to the fact that it has not been well documented and justified as a "basic skill." The unitary model presented here provides such a justification. Given that aesthetic values exist as executive principles controlling the execution of all other procedures, they are perhaps the most basic of skills. In this paper I have identified only a few areas of executive principles which should be a systematic part of teaching and learning. No doubt such theorists as Kohlberg (1983), Apple and Kins (1983), Glasser (1981) and others would expand considerably on my categories.

CONCLUSION

In this paper an instructional model for thinking skills has been presented along with the research and theory supporting it and a discussion of its implementation. The model is based on a unitary theory of human cognition and some basic assumption about the conditions for success of any intervention within public education. The intent of the model is to be implemental at any grade level within any instructional framework. At a very basic level the model is simply a linguistic framework within which teachers and students can interact about cognition. However, the model also provides a framework for curriculum reorganization and instructional pedogogy and provides an opportunity to justifiably expand what is considered basic education.

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