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ABSTRACT

Arguing that the goal of the development of thinking skills for the low-achieving student is within reach, this paper contends that an effective course on thinking skills should result in a single, well-integrated schema which is built upon the principles and processes that the course is intended to develop and should be elaborated with concrete applications. The paper reviews and critiques several existing thinking skills curricula in terms of their pedagogical structure and documented effectiveness. The paper concludes with a discussion of efforts to develop an effective and usable curriculum on thinking skills anchored in contemporary theory and research in cognitive science. (One table of data and 10 figures are included; 71 references and two footnotes are attached.) (RS)

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TEACHING THINKING TO CHAPTER I STUDENTS

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Abstract

What is it we want most for students to gain through school? We undoubtedly would agree that it is the ability to manage their lives on their own, competently, considerately, and productively.

What is it that we try hardest to teach to students in school? We undoubtedly must agree that it is reading, writing, mathematics, social studies, and science.

What is the underlying match between our consensual goals and our conventional curriculum? That is, why do we teach the things we do? There are, of course, several answers. First, within these disciplines there lie certain basic survival tools, certain knowledge and skills that all adults ought to have. Beyond that, there are also, for some students in some of these disciplines, the beginnings of what may become career-specific knowledge and skills. But we would argue that, for the random student, the real motive for including any particular topic in the curriculum runs deeper. The real motive, we would argue, derives from the potential value of that topic as a medium for teaching the students about different perspectives and modes of thought that they might apply to their own worlds.

If this is indeed the major goal of our curricular content, then it is not, in the current educational context, serving its purpose. I am willing to assert this on a single argument: The very idea that the real purpose of immersing students in such stuff is to teach thinking is strictly an adult insight.

Students, in contrast, believe too often that the reason for studying history is to memorize the facts, the reason for solving math problems is to get the right answers, and the reason for writing compositions is because they have to. If we truly intend our course materials to be the vehicles as well as the objects of thought, then that goal should not fall into the category of an *adult insight*. Indeed it should not be an *insight* at all. It should be *obvious*, and it should be obvious to students while they are in school: while they are trying to learn what we hope they will have learned by the time they get out.

The purpose of this preface is to make clear that, although this goal is currently all the rage, it is neither revolutionary nor flaky. The development of thinking skills has long been a central if somewhat elusive goal of our pedagogical agenda. The purpose of this paper is to argue that this goal is within reach.

More specifically, I will argue that an effective course on thinking skills should result in a single, well-integrated schema. The schema should be built upon the principles and processes that the course is intended to develop, and it must be richly and diversely elaborated with concrete or real-world instances of application. The creation of such a schema requires explicit treatment of elementary concepts and processes as well as their individual roles and interplay in more complex activities. In presentation, the course must be nonpresumptuous, and equally so, about what the students do know already and what they don't. And its contents must consistently be conveyed with piecewise clarity and overall direction and coherence; both teachers and students must understand, concretely and conceptually and at all times, both what they are trying to do and why.

In developing this argument, I will review and critique several existing thinking skills curricula in terms of their pedagogical structure and documented effectiveness. While the argument is anchored in contemporary theory and research in cognitive science, it has been honed through our own effort to develop an effective and usable curriculum on thinking skills. I will therefore conclude the paper with a discussion of that effort.

The current interest in teaching thinking has been provoked by the onset of the Information Era, supported by recent advances in cognitive theory, and begged by the results of domestic evaluations (e.g., National Assessment of Educational Progress, 1981, 1983) and international comparisons (e.g., Travers, 1987) of our students' higher order cognitive skills. In spirit, the movement has been directed more towards fostering excellence than overcoming the opposite. Yet there is the hope that, as the issues become better understood and the curricula multiply and mature, it will yield effective methods for correcting the special problems of low-achieving students. It is to this possibility that the present paper is directed.

TEACHING THINKING TO CHAPTER I STUDENTS

An Overview of Curricula on Thinking

In this section, I will provide an overview of existing curricula on thinking skills. I will not attempt a program by program description and evaluation of these efforts as such reviews already abound in the open literature (e.g., Chance, 1986; Chipman, Segal, & Glaser, 1985; Costa, 1985; Nickerson, Perkins, & Smith, 1985; Segal, Chipman, & Glaser, 1985). Instead, I will treat the curricula as a group, doing my best to describe their common assumptions, goals, and problems.

The fundamental assumption motivating all curricula on thinking is that there exists a certain set of skills or processes that are common to thinking in general, regardless of person, domain, or purpose. The common goal of the curricula is to teach those processes and, in that sense, all fall under the general rubric of process-oriented curricula. In terms of approach, however, they subdivide into two groups.

Within the first group, the lessons are built around complex "ecologically valid" materials such as real-world conundrums, specially written stories about the true-to-life problem-posing environments and problem-solving lessons of model compeers, the students' own writing or schoolwork, or even the contents of Great Books (see Costa, 1985). The processes targeted by this first group center on what Paul (1984) has termed "macrological skills," such as creativity and the ability to deal with complex information and multiple points of view.

Within the second group, the lesson materials are abstract, similar to those found in standardized psychometric tests of aptitude: dot matrices, geometric figures, and simple lexical or pictorial multiple-choice items. The processes targeted by this group of programs center on what Paul has termed "micrological skills," such as observation, classification, and sequencing.

A question of primary interest, for both theoretical and practical reasons, is what are the basic and universal processes that these curricula collectively endorse. The task of generating a coherent answer to this question is made difficult, but not impossible, by the cross-program differences in the levels or complexities of the targeted processes. However, there are other, more vexing obstacles to this endeavor. First, and perhaps most surprisingly, the curricula are not uniformly explicit about the processes they are intended to develop (and this is somewhat independent of whether the processes are named or numbered). Second, even when lists of processes are provided, they often reflect a sloppy partitioning of the potential space. As one example, process lists for the *Instrumental Enrichment* curriculum cite logical reasoning as distinct from inductive and deductive reasoning (Chance, 1986; Link, 1985). As another, among the 60 skills comprising deBono's *CoRT Thinking Materials* (1975), there is considerable overlap, for example, "Consider All Factors," "Input," "Expand," and "Information;" "Opposing Points of View" and "Examine Both Sides;" and "Objectives," "Define the Problem," "Target," and "Purpose." Third, where process overlap clearly does exist between programs, it is often disguised by differences in nomenclature. Thus, what one calls divergent thinking, another calls lateral thinking; what one calls sequencing, another calls operational analyses, and so on.

At a more general level, the vast majority of the programs are directed toward developing students' analytical and logical acumen. But even here, there are ardently voiced differences of opinion. Paul (1984) argues that programs intended to develop such "critical/analytic" thinking skills can be, at best, of limited, short-term value. What students need most, he argues, are "strong-sense" thinking skills, skills that support the dialectic, that generate fair-mindedness and reasoned judgment. These skills, he continues, are based on principled and *not* procedural thought; they represent a different mode of thinking from that which is emphasized by the critical/analytic approach and cannot be developed through any direct extension thereof.

Edward deBono (1984) comes down on the value of critical thinking and logic with at least as much force:

> . . . as the teaching of thinking becomes fashionable, there is the serious danger that educators will turn to the only sort of thinking they know: critical thinking.
>
> The emphasis on critical thinking has long been the bane of society and education. (p. 16)

deBono then asserts that what students lack most are *creative* thinking skills; to master these, they need training in perception. His argument is that:

> If the perceptions are inadequate, they cannot be put right by an excellence of logic. Indeed, there is a real danger that we accept an error-free argument as correct when the logic may be correct, but the perceptions on which it is based are grossly faulty. (de Bono, 1985, p. 367)

Despite the apparent disarray and disagreement, I will argue that there is, in fact, considerable commonality of goals across these programs. I would agree with Paul's (1984) position that students need develop the sort of critical but open-minded, flexible, and nonegocentric thinking skills of the dialectic. On the other hand, I would assert that the only rational path to these abilities is through the critical and analytic skills that he rejects.

Similarly, I must agree with deBono, that perceptual inflexibility or a fixedness on bad information is a major cause of irrationality and a major obstacle to creative or productive thinking. On the other hand, short of perfect knowledge, logic is the only recourse we have for detecting the incompleteness or inconsistencies of our perceptions. Actually, deBono acknowledges this himself time and again in his writings. Moreover, his own curriculum, the *CoRT* thinking program, is focused on the logical, analytical skills necessary for evaluating one's information and perceptions. deBono, in short, differs more in posture than stance from the other program developers.

In the final analysis, the major difference between programs is that with which we began: the difference in the levels of the targeted processes and principles (macrological versus micrological) and the nature of the materials (abstract versus real-world) through which they are exercised. In terms of pedagogical *goals*, even this distinction is empty: As mentioned above, the development of macrological processes presumes operational knowledge of the micrological processes; and conversely, the very reason for teaching micrological processes is to build a sound, analytic base for macrological growth. In terms of pedagogical *effectiveness*, however, the two approaches may differ significantly. Toward distilling the respective strengths and weaknesses of the two approaches, a closer examination of several programs is presented in the next section.

What Works and Why?
A Closer Examination of Six Programs

The question of what works would seem to be an easy one to answer. One need only examine the evaluation data, or so it would seem. As it happens, however, the evaluation data on these efforts do not allow straightforward comparisons. Where data exist and are easy to obtain, they are often flawed in design and control (Sternberg & Bhana, 1986). The good, if qualified, news is that virtually every reported evaluation includes evidence of some gains, and amidst the various evaluation efforts there are also some extremely positive results.

But even restricting consideration to these positive results, there is room for disappointment. As shall be discussed, the curricula are, to a greater or lesser extent, beset by at least one of the following limitations: Substantial gains tend to show up only for some students, under the tutelage of only some teachers, and only on tests that are closest in structure and content to the course itself.

A glance at the recent literature suggests there exist scores of programs on thinking skills. In fact, if one restricts attention to those aimed at school children (as opposed to preschoolers, college students, or adults), there really aren't very many. Of these, I will base the discussion in this section on only six, selected for the simple reason that they were the programs about which I was able to obtain the most information.

The next six programs fall, three and three, into the categories of macrological and micrological. The three macrological programs are *CoRT Thinking Materials* (deBono, 1975), *Philosophy for Children* (Lipman, Sharp, & Oscanyan, 1980), and *The Productive Thinking Program: A Course in Learning to Think* (Covington, Crutchfield, Davies, & Olton, 1974). The three micrological programs are *Instrumental Enrichment* (Feuerstein, 1980), *Intuitive Math* (Burke, 1971), and *Think* (C. Adams, 1971). One of the six programs, *Productive Thinking*, was designed for fifth and sixth graders. The rest were designed for Grades 3 or 4 and up.

In this section, I will address the questions of how and why these programs are more and less effective, focusing on each of the limitations cited above. As I do so, I will pay particular attention to the distinction between macrological and micrological approaches and to the special needs of Chapter I students.

Transfer

Of the three limitations, the most disheartening is the tendency for significant gains to show up only on tests that are highly similar to the curricula in content and structure. What this means, in a nutshell, is that transfer or generalization of the processes taught in these courses is limited. Yet, transfer is the primary goal of a course on thinking. If the processes don't transfer, they cannot even be called thinking. They can be called learning, or memory, or habit, but not thinking. The purpose of a course on thinking is to enhance students' abilities to face new challenges and to attack novel problems confidently, rationally, and productively. For Chapter I students, it is, moreover, to create the intellectual leverage to catch up and move on.

Whether to choose wisely among existing programs or to invent new ones, an understanding of the factors that promote and inhibit transfer is of first-order importance. My own conviction is that when the mind resists doing something that we believe to be intelligent, it is almost always because it is giving precedence to some conflicting but more important behavior. I shall now argue that the mind's apparent resistance to transfer is an exact case in point.

Recent research in cognitive science converges on the conclusion that the human mind is nothing like a piecemeal catalog of knowledge. When you learn about a topic, your memory does not just store away a list of all of the observations, facts, and events about which you have learned. Instead, the substance of each experience is reduced in memory to an extended array of primitives while its structure is preserved through an intricate set of interconnections among the primitives. More specifically, the interconnections capture all of the various relations among the constituents of the experience that were noticed consciously or unconsciously, in its processing.

The power of these memory structures, or *schemas* as they are most often called in the psychological literature, derives from the assumption that the primitives are not duplicated and are relatively small in number (Hintzman, 1986; Rumelhart, 1980). It is this assumption that explains the topical coherence of memory: To the extent that two experiences involve the same constituents, their internal representations must involve the same subsets of primitives; because of this, the occurrence of one will serve as a reminder of the other (through the partial activation of its memory). It is also this assumption that provides the means for passive acquisition of abstract, generalized, or categorical knowledge: The representations of similar precepts must, by virtue of their shared primitives, overlap such that the occurrence of any additional instance will evoke them all; thus brought to mind in unison, their commonalities, by sheer strength of number, will dominate their particulars. By the same means, whole clusters and even clusters of clusters of primitives will overwrite each other as their corresponding experiences recur. In this way, the representations for broad conceptual categories and complex situations will accrue hierarchically as successively higher levels of overlap serve to reinforce the commonalities among ever more general classes of experience. (As an example, one's general concept of restaurants reflects the distributed commonalities of one's more specific concepts of cafeterias, teahouses, and hamburger havens which, in turn, reflect the commonalities among one's individual encounters with instances of their kind.)

The foregoing description of schema theory is necessarily top-level and, although I will add to it as relevant, I cannot, within the scope of this paper, do justice to the breadth and depth of its development.

The reader interested in greater detail is therefore referred to the open literature. As a good (but rapidly aging) starting point, I recommend a chapter by Brewer and Nakamura (1984) in which major contributions and extensions to the theory are treated from an historical perspective.

In approaching this literature, however, the reader should be warned that, ignoring the many smaller differences between proposals, there are basically two versions of the theory. The version glossed above is that which is generally endorsed by psychologists (e.g., Adams & Collins, 1979; Bartlett, 1932; Rumelhart, 1980; Rumelhart & Ortony, 1977). The other version, owed first to Marvin Minsky (1975), a prominent computer scientist in the field of artificial intelligence (AI), differs significantly in its assumption about the nature and function of abstracted knowledge. The assumption, more specifically, is that the commonalities among a related set of concepts, procedures, or events come to be represented in and of themselves, as abstract knowledge "frames." The interpretation of any given situation then consists in selecting the best fitting frame against which to map it. Once the frame has been selected, the particulars of the situation are inserted into its predefined slots, like variables, or they are forgotten. Memory, thus, consists exactly and only of the instantiated frame that results.

In view of the nature of the AI challenge and the behavior of the AI programming language of choice (LISP), this second version of the theory is wholly motivated and has been highly productive. From a psychological perspective, however, it has proven untenable.

Minsky's version of the theory predicts, for example, that perceived information that is of little or no significance to the schema or frame that dominates interpretation will be forgotten, that inferences governed by the resting structure and content of the dominant schema or frame will be remembered as though real, and that perceived information that conflicts with the established schema or frame will be overridden or distorted. In fact, laboratory evidence for each of these predictions has been produced, but not consistently. In particular, recall performance is far more vulnerable to such errors than is recognition. (See Alba & Hasher, 1983, and Sanford & Garrod, 1981, Part 1, for reviews of such findings.)

Such data as they suggest that schema neither gate nor merge our memories in any reliable way, and refute the reality of the "AI version" of the theory. Yet, they are entirely consistent with the "psychologists' version" which holds that, although everything gets into memory, schemas influence the general ease and specific contexts with which it is likely to be retrieved. The "psychologists' version" of the theory gains further credence as it converges with a second and highly influential set of bottom-up memory theories known as exemplar or multi-trace memory models (e.g., Brooks, 1978; Hintzman, 1986; Jacoby & Brooks, 1984; Kahneman & Miller, 1986; Medin & Schaeffer, 1978; Smith & Medin, 1981). It is, moreover, the "psychologists' version" of the theory that is assumed in the present paper.

Schemas are essential to our ability to understand what we see and hear. For example, if I told you that I had a big dog named Fido, you would, by virtue of your schema about dogs, readily infer that Fido has four feet and fur, that he barks, that he is my pet--you would even have a pretty good notion of how big he might be. If I told you that Kathy, for reasons of genetics, was born without feet, you would feel very little compassion--if you knew she was a goldfish. If I told you that the man who had been sitting across the room from me walked out without leaving any money, you would wonder what in the world I was talking about--unless you knew I was in a restaurant.

Thus, schemas serve to organize and fill out the scant information we typically receive about the world. They are the means by which we are able to use our knowledge and experience to make sense out of raw ambiguity and to find significance in a gesture. But, notice: it was essential to know that Kathy was a goldfish; it was essential to know that I was in a restaurant. The interpretive advantage of the system depends upon your finding the *appropriate schema* through which to interpret the information at hand.

The goldfish and restaurant examples point up one more important feature of the system: Schemas bundle together information that has been related in one's experience; as a consequence, they also separate information that has not. This partitioning of memories by schemas is also generally beneficial. To see why, let us again consider an example. Imagine that you are reading about John Dean in *All the President's Men* (Woodward & Bernstein, 1976). Not once, as you read along, do you confuse "John" with King John, Pope John, John Cage or John who was in your fourth grade class. Not once do you pause to wonder if his family makes pork sausages or if his brother was killed in a car accident. On reading that John was a Baptist, you do not take him to be John the Baptist; you do not even consider the possibility. The point is that when you are thinking within a schema, your thoughts rarely wander to another, no matter how suggestive the cues.

Thus, we see that this partitioning of information by schemas is also crucial to cognitive coherence. Information that has not been interrelated in your experience is not interrelated in your memory; it is coded in separate schemas. This protects your thoughts from spurious associations and the mental chaos that would result therefrom. In the interest of teaching for transfer, however, an unfortunate side effect is that it also inhibits you from jumping between schemas, even when so doing would give you the most productive edge on a problem.

All of this makes for a very persuasive argument as to why content-oriented efforts to teach thinking skills--that is, efforts to do so in conjunction with some particular content area such as science, social studies, or arithmetic--are unlikely to succeed. Specifically, if the thinking skills are introduced and developed through specific content, they will, per force, be remembered, understood, and--importantly--accessible only in relation to that content. The resulting schema will hang together as a richly interconnected complex of knowledge about the topic. Here and there, embedded within it, will be a variety of analytic or heuristic processes and principles. From any other domain, it may be possible to access these processes and principles through explicit and pointed analogy. It also may not, depending on how integrally they are encoded in terms of the content. But their spontaneous transfer cannot be expected. If the goal of the course is to teach thinking, if it is to develop a schema that is about thinking, then the course should very consistently and very unambiguously be about thinking.

Less obviously, perhaps, the foregoing discussion of schema theory also explains why a strictly abstract, micrological approach is unlikely to produce transfer. Within the discourse on thinking skills, such approaches are occasionally described as being "content-free." What is meant by this label is that the targeted principles and processes are introduced and exercised through such materials as dot matrices, abstract line drawings, and so on. The nature of the materials is, in turn, held to be the key to transfer: Because the principles and processes are developed in the abstract, they should be conceptually neutral and, therefore, equally generalizable to all applicable problem domains.

The argument sounds good, yet there must be something fundamentally wrong with it. The disappointing transfer effects of the micrological curricula are repeated in miniature across scores of training and transfer studies in the psychological literature.

The clue is found in the term "content-free." Can a curriculum really be content-free? The answer is no: The content of a curriculum is the medium of instruction; it is the materials to which the targeted processes and principles are applied; it is the materials through which they are defined and exercised. In terms of content, the difference between content-oriented and content-free curricula is not whether or not they have it; it is whether the content they do have consists of traditional classroom matter or, say, abstract graphic designs of some sort. Most importantly and whichever the case, the content of the course defines the context within which the principles and processes will be retained and through which they may be recalled. If the goal of the course is to teach thinking and, therefore, to maximize transfer, the materials or content through which the course is developed should reflect as diverse and broadly useful a set of problem domains as is possible.

From schema theory, moreover, an important distinction develops between *abstract* knowledge and *abstracted* knowledge; it is the latter that constitutes the basis for productive understanding. If what is taught is wholly *abstract*, if it is removed from the context and conditions of its application, it will be learned as an isolated structure. As such, it will not interlace with preexisting schemata and will lack the representational microstructure through which it might be elicited in appropriate contexts. In contrast, principles and processes become *abstracted* through their repeated exercise in a diversity of contexts and problem situations. In time, as the particular instances of application overwrite each other, their distinctive features give way to their commonalities. The idea that the power of abstract reasoning derives from concrete experience follows not only from schema theory, but also from comparative studies of expert/novice performance (Chi, Glaser, & Rees, 1982; Larkin, McDermott, Simon, & Simon, 1980), prominent theories of cognitive development (Ausubel, 1968; Piaget & Inhelder, 1955/1958), and studies of the history of science (Kaput, 1979; McCloskey, 1983).

In fact, none of the programs under discussion falls cleanly into the category of abstract and micrological. The *Instrumental Enrichment* program may come closest; its own developers describe it as "content-free" (Feuerstein, Jensen, Hoffman, & Rand, 1985). Yet, integral to the full implementation of the *Instrumental Enrichment* program is a process called "bridging." Each lesson in the *Instrumental Enrichment* program focuses on one or two general principles, such as "A good strategy for self-checking is to reverse an operation" or "When two stimuli are very similar, more careful analysis is needed to distinguish the differences" (Bransford, Arbitman-Smith, Stein, & Vye, 1985, p. 188). Bridging is to occur at the end of each lesson: It consists in having the students produce and critique examples from their own experience that illustrate the relevant principle. Bridging is thus the key to transfer in the *Instrumental Enrichment* program. Yet, relying as it does on the students' own reminiscences, it must lack the efficiency and scope that a methodically designed set of generalization exercises could achieve. Evaluations of the *Instrumental Enrichment* program indicate that it does quite well at increasing students' nonverbal IQ scores; as a rule, however, it has not resulted in significant improvements or transfer to general school achievement or nonschool cognitive tasks; interestingly, exceptions to this rule tend to be had where the students' instructor for *Instrumental Enrichment* is also their instructor for other coursework (Savell, Twohig, & Rachford, 1984).

Each of the other two micrological programs, *Intuitive Math* and *Think*, is built around six basic skills (the descriptors in parenthesis are mine, added for clarity):

1. Thihgmaking (concept formation);
2. Qualification (description);
3. Classification;
4. Structure Analysis (part-whole analysis);
5. Operation Analysis (sequencing);
6. Seeing Analogies.

The goal is to enhance the students' thinking abilities by exercising these micrological skills over and over, across a diversity of problems of graduated difficulty. The problems are mostly multiple choice, fill-in-the-blanks, and so on. In format, they thus resemble the abstract exercises of the *Instrumental Enrichment* program. However, excepting those exercises used for introducing the processes, they are not abstract. Rather, the exercises in *Intuitive Math* and *Think* are designed to connect the basic processes to the content and operations of conventional school subjects: mathematics and language arts/reading, respectively. Thus, although the materials reflect a bit of a shotgun approach to content, they do indeed include considerable content. And, because the exercises are consistently presented and analyzed in terms of the six basic thinking skills, it is likely that the students' memory for the course will accrue as a single grand schema.

Both *Intuitive Math* and *Think* were specially designed for remedial work with students in Grades 4 and up and have been used quite extensively with below-norm inner-city and Chapter I populations. Each has been shown to produce not just significant, but often very impressive growth in the average achievement scores of recipient classrooms as measured by a variety of tests[1] (California Achievement Test, Comprehensive Test of Basic Skills, Gates MacGinitie Reading Test, Iowa Test of Basic Skills, Metropolitan Achievement Test, and Stanford Achievement Test) (Worsham & Austin, 1983; Zenke & Alexander, 1984).

In contrast with the micrological approaches, the macrological generally avoid the abstract. Instead, it is through a diversity of face-valid materials and the repeated application of the targeted principles and processes to them, that the macrological approaches seek to maximize transfer.

From the perspective of schema theory, this sounds like the right approach. Nonetheless, for the two most extensively used macrological programs, deBono's *CoRT* and Covington et al.'s *Productive Thinking*, evidence of transfer, as measured by improvements on standardized tests, is hard to come by (see Mansfield, Busse, & Krepelka, 1978, and Nickerson, Perkins, & Smith, 1985, for summaries).

There is, on the other hand, a stand out among the macrological curricula. This is Lipman's *Philosophy for Children*. Evaluations of this program with middle school (grades 4-8) children have repeatedly shown it to produce significant gains in reading comprehension and/or logical thinking (see Lipman, 1985, for a summary).

Three explanations might be offered for the effectiveness of Lipman's program as compared to its macrological cousins. First, it is a bit of a hybrid on the micro-macro dimension. Lipman argues that higher order thinking skills are not essentially different from the basic or lower order logical processes. They are instead but concatenations of the lower order processes, ways of using them "collaboratively and concertedly" to higher order ends (1984, p. 55). In keeping with this, the processes and principles covered in *Philosophy for Children* move progressively from the simpler to the complex, and, to clarify the simpler processes, many of the accompanying exercises are quite abstract. Despite intentions, however, Lipman is nowhere explicit about the identities of the basic processes, and the exercises designed to enhance them lack something in the way of clear or methodical progression. The program is centered upon and strongest with respect to the macrological end of the continuum.

The second possible explanation for the relative effectiveness of *Philosophy for Children* relates to its focal reading materials. The reading material, for each course in the program, is a novel: a single, well-written book about the continuing episodes of a small set of major characters with complex but consistent personalities. According to Lipman, the power of this medium is the imaginal invitation of fiction; the student comes to know the characters and their world in a deep sense, to identify and sympathize with them and, thereby, to truly participate in their adventure in thinking about thinking. Lipman is surely correct, yet there may be another feature of the use of novels that is at least as important. It gives Lipman the freedom to introduce, reintroduce, and elaborate each logical process across a diversity of real-world situations, simultaneously ensuring that all such instances will be remembered together, in the single evolving schema for the novel as a whole. In short, Lipman's courses are designed to build upon themselves both thematically and (though with a little more entropy) logically. In combination, these two features must enhance the likelihood that the resulting product, in the student's mind, will be a single, contextually rich but thematically integrated and logically well-articulated schema. From the perspective of schema theory, this would be the ideal.

The third explanation for the success of *Philosophy for Children* is less interesting than the others, but cannot be overlooked. Specifically, the program seems best suited for scholastically solid, culturally mainstream classrooms. Sternberg comments that "students from lower-class and even lower middle-class backgrounds might have trouble relating to the stories" (1984, p. 44). Further, the novels would lose at least interest and cohesion except in the hands of fairly good readers. And finally, the program demands a degree of philosophical sophistication, confidence, and mental agility that may be difficult for any but the best teachers to master. It follows, regrettably, that *Philosophy for Children* is probably not among the best options for widespread Chapter I implementation.

To summarize, I have argued on the basis of theory that for purposes of maximizing transfer, a course on thinking skills should result in a single, well-integrated schema. The schema must be centered on the principles and processes the course was intended to develop, and it must be richly and diversely elaborated with concrete or real-world instances of application. Consistently, from the evaluation data, I have shown that the programs yielding the strongest evidence of transfer are precisely those which best meet these theoretically designated criteria.

Through the discussion of the evaluation data, an additional set of variables has also suggested itself. Specifically, of the more successful programs, none was strictly macrological, and none was strictly micrological; none depended solely on abstract exercises, but all employed them from time to time. Is a mixed approach truly better, or is this a coincidence? This question will be addressed in the next section where consideration is turned to the issue of individual differences.

Before moving on, however, I would like to address a lurking caveat. Every one of the programs producing positive results on standardized tests can be criticized on the grounds that it includes exercises resembling the problems on standardized tests. Conversely, *Productive Thinking* and *CoRT*, the two programs producing least evidence of transfer as measured by such tests, are also the two most devoid of test-like exercises. For both *Productive Thinking* and *CoRT*, experimental or taught students have been shown to exceed controls in ideational fluency on problems similar to those found in the respective curricula. The effects of *Productive Thinking* have been particularly well researched, often demonstrating gains not just in the quantity of ideas students generate, but further in the quality of their ideas and in their intellectual independence and self-confidence (Covington, 1985; Polson & Jeffries, 1985).

The point is that transfer is a grey scale. Its ultimate metric is decidedly *not* performance on any particular set of test items, standardized or not. On the other hand, true thinking uncontainably promotes learning, understanding, and more thinking. It thus follows that there is one best measure of the success of such a course. That measure would assess whether impact of the course increases with time, whether students who received the course continue to outlearn, outperform, and "outadjust" their peers who did not. On this question, there is unfortunately very little data (but see Feuerstein, 1980, and Lipman, 1976).

Individual Differences

The second problem besetting courses on thinking skills is that many seem to work only with certain students. For programs that work best with the better students, the problem is obvious: Chapter I students tend not to be the better students. However, any insensitivity to individual differences takes on more global import when the target population consists of Chapter I students. Specifically, as a group, better students tend to be relatively homogeneous in terms of general knowledge and school skills; they are deemed good students, after all, by virtue of the fact that they have learned, with reasonable consistency and alacrity, that which has been taught. The same is not true of low achieving students; whether quick or slow, and they may be either, their defining characteristic is that their *school* skills and knowledge fall short of grade expectations in one or more domains. It follows that the most promising program for Chapter I implementation will not be geared to either the best or the worst. Rather, to be successful, it must be appropriate across a broad and complex space of individual differences.

This point spells immediately into yet another argument for teaching thinking skills separately rather than as an adjunct to any conventional content area. That is, to think about history, a student must first know a certain amount of history; to read critically, a student must first read at a certain level; etc. Because they offer their developers so much freedom in selecting and structuring content and materials, process-oriented approaches offer a medium that can be relatively free of such impediments. Process-oriented approaches are therefore your best bet if the students to whom you would like to teach thinking skills are either young or low achievers. Process-oriented approaches are also your best bet if the students differ from one another in their entry levels of achievement--and, do note: pull-out or not, they always do.

Of the macrological programs, effective use of *Philosophy for Children* is, as mentioned above, practically restricted to better classrooms. Similarly, *Productive Thinking* has been used most frequently and successfully with above average students (Chance, 1986; Covington, 1985).

Indeed, of the macrological programs, *CoRT* alone claims equal usability and success across high ability, low ability, and mixed ability groups (deBono, 1985). The wider usability of deBono's program is owed to the nature of his materials. They consist of problems that have no correct answers, but whose proper airing may involve consideration of a number of factors and points of view, all of which should be available through common sense and common knowledge. Examples of these problems include, "What makes a TV or radio program interesting?" "Mail services lost a lot of money. If you were running these services, what alternatives might you suggest?" and "A father forbids his 13-year-old daughter to smoke. What is his point of view and what is hers?" (deBono, 1985). The purpose of the problems is to exercise *CoRT's* "tools" or thinking principles. The *CoRT* program includes 60 named principles although, as mentioned earlier, there is considerable redundancy among them. In the main, the principles are directed towards brainstorming, suspending judgment while brainstorming, identifying the positive, negative, and interesting or unusual features of the brainstormed ideas, recognizing different points of view, and putting it all together. In class, the principles are named but not defined except by way of the teacher's chosen examples. For the core of each lesson, the students are divided into groups of four or five. Within these groups, they discuss each problem, giving special attention to the tool of the day. Then the groups report their ideas to the class as a whole. In short, the lessons pivot on appealing problems that involve no reading, no writing, no specialized knowledge, and no wrong answers--just talk, and all kinds of people love to talk. Hence, its universal usability.

But what about its success? deBono eschews standardized tests--"they are not sensitive to the range of thinking skills in which the *CoRT* program offers instruction" (deBono, 1985, p. 382). He prefers tests of his own devising, testimonials, and examples. Here is an example:

> I was once teaching a demonstration class of 10-year-old children in Sydney, Australia. I asked them whether they would like to be given $5 a week for attending school. All 30 of them liked the idea and gave their reasons for doing so (buy sweets, chewing gum, comics, etc.). I then introduced the idea of the PMI [a *CoRT* tool] and asked them to apply this to the suggestion, working in groups of five. After 4 minutes, I asked for their output. They raised the following kinds of issues: Parents would stop pocket money, schools would increase charges, bigger boys would beat up smaller ones--and where would the money come from? Twenty-nine out of the 30 had now completely reversed their opinion. This was without any suggestion from me as to which considerations they should bring to mind. This example illustrates the purpose of *CoRT* thinking: the use of a simple perceptual framework to bring about a conclusion through exploring the experience in a more thorough manner (deBono, 1985, pp. 385-386).

I have to say that I am underwhelmed by the quality of thought shown in such examples.

I have seen the *CoRT* program in action. I was highly impressed with the enthusiasm and the mental activity it provoked in the classroom, and am comfortable with the idea that it generally does so. I believe that the *CoRT* program may exert a strong effect on the attitudes of low achievers, that it may give them a genuine sense of their own permission to think. Such an outcome can only be considered invaluable and should not be downplayed. On the other hand, I remain skeptical about the extent to which the program hones its students' critical or analytic abilities.

The *CoRT* program aside, it is the micrological courses, *Instrumental Enrichment*, *Think*, and *Intuitive Math*, that have been used most often and most successfully with low achieving students. I suspect that the apparent advantage of the micrological over the macrological programs with this population is real and derives from the characteristic difference in materials as well as structure. Turning first to materials, all of the micrological programs rely on abstract materials at least for introductory purposes. At a cognitive level, there are two advantages to such materials. First, they offer a means by which the targeted processes and principles can be explicated and exercised without presuming any specialized background knowledge on the part of the students; again, this feature has special merit when the students are of low or mixed achievement levels. Second, abstract exercises, as they are relatively meaningless by definition, remove the conceptual distraction potentiated by content-rich exercises. They thus allow for the instructional exchange (and the resulting memories of it) to be unambiguously focused on the processes and principles at issue.

In terms of structure, the salient aspect of the micrological approaches is that they include explicit instruction and labeling of the micrological principles and processes. Because of this, they are prepared with both the conceptual and terminological scaffolding to analyze and discuss the macrological issues explicitly when they do arise. This is seen as an advantage on two dimensions. First, it provides the necessary components for sound direct instruction. The definitive feature of direct instruction, whether achieved through guided practice, modeling, Socratic Inquiry, or discussion, consists in the explicit treatment of the substeps of a thought process and of the considerations pertaining to when and why each of those substeps is appropriate. Instruction of this kind is widely held to be an especially effective means of developing students' appreciation of the intellectual processes as opposed to the contentive products of a discipline (Anderson, Hiebert, Scott, & Wilkinson, 1985; Pintrich, Cross, Kozma, & McKeachie, 1986; Rosenshine, 1986). Without explicitly addressing the substeps of a complex process, the best the macrological approaches can offer is indirect requirements for their exercise (see deBono, 1985). Second, the explicit articulation of the microprocesses, first by themselves and later as components of more complex or concrete challenges, should lead to a stronger core as well as richer and thus more traversable interrelations in the schema the students develop.

Even so, an equally strong but different case can be made for both macrological and content-oriented approaches, especially as they build upon information of real-world and scholastic relevance. The strong proponents of this case are cognitive psychologists, and the reason for their adamancy came as somewhat of a surprise to themselves. For the last 25 years, the field of cognitive psychology has been devoted to understanding the nature and limits of people's intelligent behaviors. Until very recently, the research has been focused all but exclusively on all-purpose processing modes and capabilities. Then, due to a variety of forces--the influence of computer scientists in the field of artificial intelligence, the resistance of language to being usefully modeled in the abstract, the uncontrollable influence of semantics on memory phenomena--researchers began to attend to the effect of knowledge on their experiments instead of trying to cancel it out.

The results have been persuasively summarized by Robert Glaser (1984). In essence, the various processing modes and capabilities that had already been postulated were reaffirmed; they were every bit present and generally behaved as expected in these new, knowledge-rich, experimental designs. The exception was that they differed negligibly across individuals: Whether comparing experts and novices in some domain, high and low scorers on aptitude tests, or even adults and children, the differences in performance proved due, most of all, to differences in knowledge.

The findings on the relationship between knowledge and performance have constituted major support for the theory of schemas. In particular, results such as those just described virtually force the conclusion that improvement in cognitive skills . . .

> . . . takes place through the exercise of conceptual and procedural knowledge in the context of specific knowledge domains. Learning and reasoning skills develop not as abstract mechanisms of heuristic search and memory processing. Rather, they develop as the content and concepts of a knowledge domain are attained in learning situations that constrain this knowledge to serve certain purposes and goals. Effective thinking is the result of 'conditionalized' knowledge--knowledge that becomes associated with the conditions and constraints of its use. (Glaser, 1984, p. 99)

A large proportion of the Chapter I population is comprised of children who, for reasons of ethnicity, poverty, or parental education, fall outside the mainstream culture of our society. The implication of these issues for such children is so important that it bears restatement.

Cognitive theory and research indicate that the way in which we perceive and interpret our worlds depends most of all on the worlds we have experienced in the past. Our minds can be described as the organized memories of whatever we have experienced, either consciously or tacitly. Thinking, understanding, and learning can be described as processes of retrieving or constructing interrelations among subsets of our knowledge that coherently model the phenomena under consideration.

If this view is correct, then cross-cultural differences in achievement are to be expected. Our knowledge must vary at several different levels with the culture in which we live. At the most basic level, the phenomenal world may differ markedly across cultures, and even where it overlaps, the full or contextually elaborated meanings of particular objects or events may nonetheless differ significantly. To this extent, our direct knowledge of the world, both simple and complex, will be culture specific. Our cultural environment also influences the kinds of knowledge we are likely to gain through vicarious experiences. Culture shapes not only the topics but the social functions of the oral language around us. Further it determines the nature and availability of other sources of vicarious experience, such as books, newspapers, and television programs.

Thus, our cultural environments are strong determiners of the kinds of experiences to which we are haphazardly exposed. In addition, however, there are social differences between cultures which must affect our cognitive development in a more systematic way. Specifically, cultures differ in the *uses* they make of thinking and knowledge. This impacts not only on the kinds of thinking and learning a culture fosters, but also on the attitudes it fosters toward thinking and learning. In a technologically sophisticated society, thinking and learning are prize commodities. They are highly valued both socially and on the marketplace and, like other prize commodities, are sought in their own right. That is, the technological society carries an atmosphere that is not only conducive to thinking and learning but, further, to thinking and learning about thinking and learning.

Our educational system is both the product and promoter of this cultural syndrome. It is our institutionalized best effort to provide for our children within the system--to pass on our culturally endorsed fortunes, as it were. We have designed our formal educational system to expand and elaborate on those skills and values which our children have, in any case, been reared to accept and pursue. By opening the educational system to children with different backgrounds, we offer to them the opportunity to move into and up in our social structure. The problem is that to the extent children lack the knowledge and values that the system presumes, it must be extremely difficult for them to assimilate those which it offers.

A good course on thinking skills would be an invaluable boost for such children. Ideally, it would give them the critical, analytic, and organizational abilities and attitudes to make the most of the information they do have and will be exposed to. But, for maximum impact, the course must be content-rich. For Chapter I students, the provision of content is of utmost importance in itself; it is a fact of intellectual life, that the more you know, the more you learn. Further, harkening back to the section on transfer, the content provides the links through which the learned thinking skills will be activated and applied to issues and challenges encountered beyond the boundaries of the course itself.

Returning to the programs with an eye toward the issue of individual differences, *Think* and *Intuitive Math* seem the best choices for Chapter I implementation. They are structured for assimilation by low achievers, and their content has been carefully contrived to connect to and enhance the students' performance in language arts and math, respectively.

On the short side, these two programs might be criticized for relying too much on short-format exercises. One negative of this spoon-sized delivery system is that the exercises are occasionally found to be simplistic, repetitive, and boring (although the harder exercises are reported to be exciting) (Toczynski, 1984). Another is that by relying on short-format exercises, which are inherently limited in complexity or dimensionality, the program moves too little toward the dialectical and macrological skills that support more general intellectual independence rather than just grade-level studentship. Moreover, the programs might be criticized for being too closely tied to the academic regimen they seek to enhance and, in particular, to the basic skills of those regimen. Of particular relevance within this section, the two programs are by no means indifferent to students' entry levels of achievement. Nor, I suspect, could they be, given their concentration on the remediation of domain-specific skills. Instead the programs are deliberately tailored to students' entry levels of achievement. Each has been developed across a series of levels, and Innovation Sciences, Inc., provides pretests for determining the most appropriate level for any given group of students. In keeping with this, the programs appear most successful under a statistical lens: They very often advance the average test scores of the classes with whom they are implemented. However, whether for reasons of pretesting error or nonuniversal assumptions about the sorts of skills students need, there are inevitably individuals within groups and occasionally whole groups of students for whom the programs produce little or no measurable impact. These drawbacks aside, *Think* and *Intuitive Math* look quite attractive for Chapter I purposes. On average, they do seem to arm students with not just the basic skills but, further, the basic understanding and attitude to move on.

Usability by Teachers

The third limitation, that of how easily the course can be implemented, is not a direct problem for Chapter I students. Indirectly, however, it is critical. To invest in their widespread dissemination and, thereby, to gamble the time and money they require, we should expect the curricula to be usable and effective in the hands of whichever teachers draw the straw. And we should expect them to be so without requiring undue time for lesson preparation and management in or out of class.

The profession of a teacher is teaching. A good teacher is invaluable precisely for her or his ability to understand, manage, and communicate with students. A well-designed curriculum should support those efforts, not divert them.

I would argue that it is fundamentally irresponsible for a curriculum to list major activities while expecting teachers to invent the materials or the substance of the lessons for getting them done. Of course, there are teachers who like to design their own lessons and materials. Of course, every teacher occasionally runs across materials, topics, or ideas that she or he wants to add to the lesson plan. Of course, all teachers regularly modify and adapt curriculum materials to best suit the interests and abilities of their own students.

However, one *should not expect* teachers to produce the bulk of their instructional materials any more than one expects medical doctors to invent medicines, actors to direct their own movies, or Presidents to write their own speeches from scratch. To be sure, there are some teachers, doctors, actors, and Presidents who do such things. But whether they do them is really quite independent of how well they carry out the challenges of their principal profession.

By extension of this position, I would further argue that a well-designed curriculum should not require large amounts of inservice training. A heavy inservice requirement is inconsiderate of teachers' time and school budgets. And worse, it is a symptom that the success of the curriculum depends not on the guidance and materials it provides, but on the individual efforts of teachers to interpret and go beyond what it provides.

The considerateness of curriculum materials is even more important if the topic of the course is new. When designing a curriculum in a traditional domain, such as grammar or geography, one can afford to be a little sloppier: Teachers will readily fill in the gaps, drawing on their own prior coursework and knowledge of the domain. In contrast, most teachers have not had many courses on thinking skills. To the extent that a curriculum on thinking skills is not self-contained and comprehensible, it would be almost reasonable for teachers to throw up their hands and quit it.

Of the curricula under consideration, both *Philosophy for Children* and *Instrumental Enrichment* require lots--on the order of weeks and months--of teacher training, and the outcomes of each appear highly sensitive to teacher variables. For the CoRT program, teacher training is recommended, but deemed unnecessary; on the other hand, even deBono (1985) acknowledges that the success of the lessons must be highly dependent on the teachers' style and mental flexibility. Other than reading through the appropriate sections of the *Teacher's Guide* prior to each lesson, *Productive Thinking* requires no special preparation of teachers; but again, its effectiveness seems to be quite sensitive to individual teacher variables. Finally, both *Think* and *Intuitive Math* suggest one week of pretraining for teachers, although effective use of the program by regular classroom teachers has been reported after as little as one day of preparation (Worsham & Austin, 1983). There is a trade-off here: In lieu of being training intensive, both *Think* and *Intuitive Math* are materials intensive. The implementation of these two programs requires purchase of a package including such things as individual student workbooks, "moderator guides" including teacher scripts and answer pages, response pads, tape cassettes, student progress records, and red, white, and blue counters.

One More Program: Odyssey

I turn now to a new program entitled *Odyssey: A Curriculum for Thinking* (M. Adams, 1986). The program was developed through a collaborative effort of Bolt Beranek and Newman, Harvard University, and the Venezuelan Ministry of Education. The project was funded by Petroleos of Venezuela and sponsored by Dr. Luis Alberto Machado, then Minister for the Development of Human Intelligence of the Republic of Venezuela. I give the program special attention not just because it is our own but further because (a) it was designed and implemented in the face of exaggerated forms of virtually every curriculum-breaking problem one might imagine, (b) it is structurally unique, embodying the theoretical desiderata for which I have argued in this paper, and (c) it worked as measured through a relatively large-scale and rigorous evaluation effort.

Problems Confronted

The experimental implementation and evaluation of the program was conducted solely in Venezuelan "barrio" schools, a designation indicating that the students came from homes with low social-economic status and minimal parental education. The course was administered exclusively to seventh grade classes, but the students ranged from 10.6 to 17 years of age. The students, moreover, differed at least as widely from one another in school skills, general knowledge, motivation, social behavior and virtually any other relevant dimension one might name. The teachers with whom we worked ranged from very marginal to excellent, and we knew this would be true of the teachers who might be asked to use the curriculum in the future. Because the goal was to develop a course that could be widely disseminated in Venezuela in our absence, it had to be self-contained; it had to be designed such that it would be usable without extensive teacher training and such that it would resist deleterious transformations in transmission. Finally, because of the funding system in the schools, we knew that future use of the course in Venezuela would be generally precluded unless the associated materials were inexpensive to purchase.

Curriculum Design

Odyssey is, relative to the previously discussed programs, a come-lately effort. This was a tremendous advantage in terms of defining its structure, as we had both the wisdom of hindsight on previous efforts and the benefit of contemporary theory and research in education and cognitive psychology.

From the outset, our challenge in writing the *Odyssey* curriculum was defined. We sought the focus, analytical force, and pedagogical range of the micrological approaches; we wanted to convey, very explicitly, both the nature of the basic processes and their interrelationships; and we wanted to reach the least advanced students without losing the most advanced. We sought the epistemological leverage of the content-oriented approaches: We knew our thir ing skills had to be thoroughly enmeshed in conceptual knowledge of direct scholastic or real-world evance. We sought the intellectual complexity and dialectical reflection of the macrological approaches. And we wanted the skills we taught to transfer, to be recalled and applied to whatever amenable challenges the students might encounter beyond the confines of the curriculum itself. To meet this challenge, we exploited the theory of schemas and developed a content-rich but process-centered design within which the macrological is systematically built upon the micrological.

Before delving further into *Odyssey's* design, a pair of studies by Gick and Holyoak (1980, 1983) may be especially instructive. In their first study (1980), Gick and Holyoak set out to assess the way in which people's familiarity with the solution to one problem influences their approach to a second. As their target problem, Gick and Holyoak chose a medical problem (from Duncker, 1945) which very few people (fewer than 10% in Gick and Holyoak's sample) tend to solve without any help. To demonstrate transfer, subjects were asked to solve the medical problem immediately after reading and memorizing a story that described the setting and solution to a logically analogous but semantically different problem. As expected, this procedure produced an increase in the number of subjects who eventually generated correct solutions to the medical problem. Yet, the transfer effect was disappointingly weak: A few subjects seemed to capitalize on the guidance provided by the priming story spontaneously; however, the majority did so only after the experimenters provided a directive hint as to the relevance of the priming story; and, even with this hint, a significant number of subjects never produced the solution. This basic pattern of results held whether subjects had been asked to work with the priming story before being given the medical problem or only after they were stuck on the medical problem. It also held whether they had been asked to read and recall the priming story or had actually solved it themselves. Furthermore, not even the hint helped much unless the priming story was *very* similar to the medical problem in structure.

Overall, then, Gick and Holyoak's first study (1980) demonstrated that their subjects (a) generally failed to notice the analogical relationship between the problems on their own, and (b) had trouble recognizing the relationship even when told that it was there. In view of this, Gick and Holyoak's second study (1983) was directed toward finding a way to overcome such resistance.

To this end, Gick and Holyoak (1983) first tried providing subjects with either an explicit statement or a graphic representation of the solution principle. But, whether these aids were presented in isolation or in conjunction with the priming story and its solution, the majority of subjects still failed to solve the medical problem without the hint.

Next, Gick and Holyoak tried giving the subjects two different study analogies prior to the medical problem while asking them, not to recall the individual stories, but to write a summary of the similarities between them. This procedure seemed to work a bit better: About 45% of the subjects solved the medical problem with no hint, as opposed to about 30% in the conditions involving a single story plus the principle or diagram. With the hint, as in virtually all of the previously described conditions, about 80% succeeded.

Finally, Gick and Holyoak applied brute force. Again subjects were given two different priming stories with the instructions to write a summary of their similarities but, this time, appended to the end of each of the stories and in identical wording, was an explicit statement of the solution principal. At last, the majority (62%) of the subjects demonstrated spontaneous transfer, solving the medical problem with no hint. With the hint, another 20% did so, such that the total success rate again equaled about 80%.

Gick and Holyoak repeated the latter procedure once more, this time varying the similarity of the two priming stories to each other. In addition, the explicit statement of the solution principle was either eliminated or substituted with a graphic representation. Without the graphic aid, performance fell to the level of earlier experiments. With the graphic aid, however, the majority of the subjects again solved the medical problem with no need of a hint: 62% with priming stories that were very similar to each other and 53% with priming stories that were not. Given the hint, moreover, virtually all of these subjects (92%) succeeded.

To better understand the mechanism for such transfer, Gick and Holyoak analyzed the subjects' written comparisons of the two priming stories for the completeness with which they described a schema for the logical structure of their solution. It is from these analyses that the real force of the study derives. Specifically, even among those subjects who produced poor schemas, a certain number proceeded to solve the medical problem. However, and regardless of the experimental condition, virtually *every one* of the subjects whose summary included a *good* description of the solution schema, proceeded to solve the medical problem with *no need of a hint*. The probability with which subjects generated a good solution schema was increased by the provision of either the statement of the principle or its graphic representation, and was highest when one of these aids was presented in conjunction with two priming stories that were superficially dissimilar from each other.

From these results, we may infer that there exist two different types of transfer. The first, which we will term *direct transfer*, involves a direct mapping from one problem-solving situation to another and is enhanced by the superficial similarity between the problems and the provision of a hint. As valuable as direct transfer might be, it is highly dependent upon context and, by implication, cannot be trainable in any generally and robustly useful way. The second type of transfer, which we will term *mediated transfer*, is enhanced by the superficial dissimilarity among the training problems and by the provision of such aids as statements of principle and abstract diagrams. Mediated transfer may transcend superficial differences between problem situations since the edge on a novel problem is gained not through direct mapping to the training problems but through mapping to the principles and procedures that have been abstracted from those training problems. It is mediated transfer that we seek to promote through the *Odyssey* curriculum and, consistent with Gick and Holyoak's studies, we pursue this goal through brute force: The concepts and processes that the students are to abstract are developed across a diversity of exercises and thought-provoking challenges, and they are verbally summarized, graphically supported, and consistently labeled throughout.

In overview, the curriculum we produced consists of six Lesson Series or books. Each Lesson Series is divided into two or more Units, representing subtopics. The Units themselves are comprised of three or more 1-hour lessons. Table 1 provides a list of Series and Units and, in parentheses, the number of lessons in each Unit. The table also includes brief descriptions of some of the main objectives of each Unit.

[Insert Table 1 about here.]

In the first Lesson Series, *Foundations of Reasoning* (Adams, Buscaglia, deSanchez, & Swets, 1986), each of our targeted thinking skills is introduced through the sorts of abstract teaching materials typical of micrological approaches. Then, through the balance of the course, these same thinking skills are used, and thereby refined, elaborated and contextualized, over and over again, as the means of developing the various macrological and domain-specific challenges of each of the other Lesson Series.

Our basic position in designing the curriculum was that thinking, in any domain, involves two basic components: information and interpretation. We therefore designed the course so as to develop a set of *processes*, *concepts*, *strategies*, and *attitudes* that would support the reflective, methodical, and productive exploitation of these two components.

Of these, it is the *processes* that serve as the backbone of the course. That is, it is the processes that are to unify and empower the grand schema that the course is meant to instill in the students. At the first level or very core of this schema is the process of analyzing information in terms of dimensions (e.g., color) and characteristics or values on those dimensions (e.g., red, blue, green). Around this core, we built four "first-order" processes: *classification*, *hierarchical classification*, *sequencing*, and *analogical reasoning*. These are called first-order processes because they are in fact nothing more than structures for comparing characteristics within or between selected dimensions.

Thus, the design of the course consisted, first, in explicitly and methodically developing the process of dimensional analysis. Upon that, we explicitly and methodically developed the four first-order processes. And, finally, upon those, we explicitly and methodically developed as diverse a set of content-specific and intellectually complex extensions as we could squeeze in. As examples, paragraphs are treated as classes of ideas, and larger text structures as hierarchies. Metaphors, allegories, and families of logical and mathematical word problems are analyzed in terms of the implied dimensions of comparison, explicitly identifying the underlying analogies. Complex decisions are undertaken by identifying the dimensions along which the choices differ from one another and then by ordering their characteristics by preference and their dimensions by importance. And, moving toward the dialectic, students are given considerable exercise in identifying the underlying assumptions and implicit information in text; in analyzing the logic and assessing the nature and function of argument in exposition as well as debate; in identifying the goals and points of view of authors and of the characters in stories; in evaluating and redesigning or rewriting inventions, procedures, and information from different perspectives; in revising opinions; and in compiling, interpreting, and evaluating information on complex, ill-structured problems. Through these excursions, we hoped to extend the core processes with the particular conditions and constraints required to make them appropriate to a variety of scholastic and real-world applications.

While structured on process, the curriculum is also rich in *concepts*. Many of these are specific to a particular domain of application (e.g., antonyms, synonyms, and propositional terms) or to the particular content through which an application is developed (e.g., ballast, adherence, and googol). Moreover, we did not shy from introducing new information to the students. To the contrary, within each domain of application, we made an effort to construct examples and exercises that were both rich and diverse in content. The goal was to make the process-schema rich in knowledge, to maximize the variety of contexts from which it might be spontaneously accessed.

Importantly, there are also a few *concepts* that are methodically raised and elaborated in every Lesson Series. Each of these core concepts deals with some aspect of the nature and quality of the information available for interpretation. They include the concepts of explicit versus implicit information, certain versus probabilistic or suggestive information, positive versus negative information, relative versus absolute information, relevance, consistency, credibility, goals, and point of view.

A number of *strategies* are also developed and used throughout the course. As examples, these include working backwards, the process of elimination, searching for counterexamples, systematic trial and error, and constructing tabular or graphic representations. The essential characteristic of strategies is that they help guide the search for or organization of information. They thus differ from processes in that they play no direct or necessary role in solving a problem. On the other hand, used methodically, they can make the solution of a problem much, much easier.

Finally, the course is intended to instill certain *attitudes* or modes of learning and thinking in the students. These include, for example, a healthy appreciation of knowledge and the rewards of self-discipline, a willingness to explore and analyze information, a readiness to critique one's beliefs and point of view, a strong notion that the structure of everything, from pencils to literary genre, reflects its intended function, and most of all, the conviction that--whatever it is--it *can* be understood. We tried to reinforce these attitudes at every possible opportunity.

Against such claims, it is appropriate to provide a fuller picture of *Odyssey's* structure and content. To this end, I will briefly describe how the process of dimensional analysis is introduced, how it is used to develop the logic of the first-order processes, and how combinations of those basic processes are then used to develop an analytic approach to a sampling of the higher-order challenges in the curriculum.

Introduction and dimension analysis. The ability to parse the world into elementary characteristics and the dimensions of variation to which they pertain is foundational to physics, mathematics, formal logic, and, moreover, virtually all formal disciplines. *Odyssey* is built upon the premise that such explicit analysis is of foundational utility for cogent thinking in any domain. On this view, characteristics and dimensions are introduced at the very start of the course.

More specifically, the course begins with the thought that everything that any one of us has learned has been learned in one of two ways: directly, through our own observations and experience, or indirectly, as conveyed or described by others. These others have, on their part, gained the information they convey either directly, through their own observations, or indirectly, by way of still others. As the analysis is extended, the point is ultimately forced that whatever we know or can know must be based on somebody's direct observations. It follows, therefore, that in the abilities to conduct, interpret, and pass on our observations carefully and accurately, lie the seeds of human knowledge.

The students are next challenged to describe things. Inevitably, they do so characteristic by characteristic, such as this thing is small, white, and round (spherical); it's light; it bounces; and it's used for playing ping-pong. From there, it is easy to get the students to produce reasons why it might also be a good idea to observe things in a characteristic by characteristic manner. But, of course, having made and justified the suggestion themselves, many students are naturally convinced that it is obvious or even banal; it is what they always do and do quite well. Lest this be the end of useful discussion from their point of view, we proceed to confront them with a series of faulty illustrations (see Figure 1). Their challenge is to determine what is wrong in each. While the task is one of straightforward observation, it is, by design, sufficiently easy that everyone succeeds with most of the drawings but sufficiently difficult that virtually no one succeeds with all. The students thus leave the first lesson with the motivating discovery that their own observational powers are perhaps not quite as good as they might be. They also leave the lesson with an introduction to the nature of characteristics, to the genre of interactive exchanges and structured discovery through which the course will evolve, and most importantly, with a sense of where the course is going--it is to be about information and interpretation: the substance and process of thinking.

[Insert Figure 1 about here.]

The next several lessons are ostensibly directed to the process of comparison. Their purpose is to introduce the concept of dimensions. As is typical of the course and necessary for the coherent conceptual growth it seeks, the first of these lessons is begun with an exercise designed to recall and review the central ideas of its predecessor: The students are asked to describe or list the characteristics of an object depicted in their workbook. They are then given a second drawing and asked to describe how it differs from the first. The basic concept of a dimension follows directly and concretely as the students are led to discover that their comparisons follow a system: characteristics are compared in kind--color with color, shape with shape, height with height, and so on.

The balance of these lessons is directed toward reinforcing the concepts of dimensions and characteristics and extending them beyond the simple perceptual domain. The students are given a variety of exercises in identifying and naming dimensions and characteristics. In addition, when the comparison process is shifted from differences to similarities, the critical notion of relative description is introduced: Whether or not two items are adjudged to be similar depends upon the purpose and field of comparison.

The first-order processes. The remainder of the first Lesson Series is principally devoted to developing the four first-order processes: simple classification, ordering, hierarchical classification, and analogies. Again, each of these processes is but a structured means for relating characteristics within and between dimensions.

Simple classification consists in selecting a dimension of interest and then grouping objects or information according to their similarities and differences on that dimension. Thus, beyond the concepts and processes involved in dimensional analysis, simple classification requires little more than the recognition that any set of objects can alternately be classified or grouped according to their similar ies and differences along as many dimensions as they can be described (see Figure 2). To support this point, the lessons on classification provide exercise in classifying sets of abstract and familiar items in multiple ways and in articulating the dimensions and characteristics governing given classifications.

[Insert Figure 2 about here.]

The last lesson of the Unit is on hypothesis-testing and is built upon the sorts of conceptual formation problems (owed to Hovland, 1952) that have become so familiar in both classroom packages and the psychological literature. The problem shown in Figure 3 illustrates how structured discovery is deployed to strengthen the impact of these problems. Specifically, the problem shown in Figure 3 is indeterminate; as it happens, the essential characteristic of "tweegles" is that they have feathers. This problem is presented well into the exercise set and, thus, only after the students have become quite facile in solving its determinate cousins. The purpose of the problem is to make forceful the previously discussed notion that positive information or positive instances of a concept are essential for purposes of formulating a set of candidate hypotheses. A similarly indeterminate problem, including only positive instances of a concept, is provided to establish the critical and delimiting function of negative information. Having been caught by these two problems, the students are better prepared and motivated to approach the remainder of the exercise set with the analytic attitude it is intended to develop. Furthermore, the distinct functions of positive and negative information will reemerge time and again, especially in lessons within the *Verbal Reasoning* (Nickerson & Adams, in press), *Problem Solving* (Grignetti, 1986), and *Decision Making* (Feehrer & Adams, 1986) Series.

[Insert Figure 3 about here.]

Ordering is the process of discovering, not commonalities in the characteristics of a group of items, but commonalities in the differences between them. Can the items be arranged such that their characteristics along some specified dimensions are consistently increasing (decreasing, alternating, or cycling)? And, if so, how do the characteristics on other dimensions of interest then pattern themselves?

The introduction to the Unit is built upon problems requiring extrapolation of sequences. Because the problems presented for independent seatwork follow a multiple-choice format (see Figure 4), the logic and procedures they require is basically the same as that involved in classification or concept identification with a significant exception: The students are additionally required to identify the nature of the sequence as progressive, alternating, or cyclical.

[Insert Figure 4 about here.]

The students are next introduced to the concept of an orderable dimension (e.g., height, weight, numerosity) and given a variety of exercises and simple orderings designed to force consideration of subtended issues of symmetry, reflectivity, transitivity, and connectivity. The exercises in the Unit are diverse, allowing the students to explore the mnemonic value of ordering, the interpretability it lends to tables and graphs, and even to make "movies" by ordering, stacking, and rapidly flipping through still pictures. Beyond reinforcing the concepts, processes, and observational discipline involved in ordering, such exercises are intended to be surprising or entertaining and, thereby, to make the issues at hand more memorable.

More generally, a certain degree of playfulness was built into the curriculum for pedagogical as well as social or attitudinal reasons. That is, within *Odyssey*, the initial definition and development of the basic processes is largely mediated through abstract exercises. This approach was adopted, as explained earlier, in the interest of maintaining focus on the basic processes per se and of maximizing their effectiveness across individual differences in conventional school skills and knowledge. However, because abstract exercises are, by definition, relatively meaningless, they are far from ideal in the interest of maximizing the processes' memorability--and the very structure of the course presumes their memorability. Before leaving the introduction of any given process, we had to do what we could to ensure that its representation would be sufficiently rich and fissile to be accessible when it was time to recall it. The most obvious means of so doing might be to import a few relatively well developed knowledge domains to the situation. Yet, in order for the course to be effective across differences in students' background knowledge, it had also to be nonpresumptuous about the students' background knowledge. Liberal recourse to traditional school knowledge was, we felt, too risky for these critical, introductory lessons.

The use of "interesting" or "entertaining" materials was seen as an escape from this dilemma. Specifically, to be interesting or entertaining, information or events must violate or otherwise surprisingly interlace with one's prior intuitions and expectations. Thus, information can be potentially interesting or entertaining to an individual only if that individual already possesses the body of conceptual knowledge which it presumes. Information can succeed in interesting or entertaining an individual, only to the extent that she or he brings that conceptual support to bear and, further, reflects upon and plays it with new interrelations. In playfulness, therefore, lie the requisites of building a robust schema.

In the context of orderable dimensions, the issue of relative description is naturally raised again. With it, through structured discovery, we take the opportunity to introduce the concept of implicit information and its critical dependence on context and on the background knowledge and point of view of its interpreter. Two problems from one of the exercises used to develop this point are shown in Figure 5. To firm up these issues, the Unit ends with an exercise on Sneaky Advertisements, for example, "This paint remover is fast and easy to use;" for each, the students are required to identify the missing but invited comparison.

[Insert Figure 5 about here.]

Hierarchical classification is the process of dividing classes into subclasses and provides the essential logic for part-whole analyses and, more generally, for coherent comparison of items across multiple dimensions. After establishing the basics, the students are given exercises in generating classification hierarchies from lists of topics and subtopics (as in the organization of a book), from lists of book titles (as in the organization of libraries), in drawing inferences about similarities and differences from a tree-graph of Indo-European languages, and in analyzing the dimensions of a problem space orthogonally so as to solve brain teasers (as in experimental design). In the last lesson of the Unit, this logic is developed as a strategy for playing the game of Twenty Questions, thus introducing the students to the rudiments of Information Theory.

Analogical reasoning is the process of discovering comparable relationships between otherwise disparate sets of information. It is often said that the analogy is our most powerful tool of creative thought. On reflection, however, it becomes clear that it is not sound analogies that hold such productive potential, but unsound ones--and even then, only given the analytic powers to determine exactly how the analogy is unsound. Only given an explicit understanding of how one case is *and is not* analogous to a second, can one efficiently capitalize on one's knowledge about the first while seeing clearly how it must be modified or extended to fit the second. Analytic understanding of the logic of the analogy will be required again and again throughout the course. The presentation and treatment of the analogy in *Odyssey* is directed precisely toward developing this sort of analytical rigor.

Conventionally, the terms of an analogical exercise are presented in a list and separated by colons, for example, kittens : cats :: foals : horses. Sometimes, for clarity, the colons are replaced with words, for example, kittens are to cats just as foals are to horses. In either case, the left-to-right listing of the terms obscures the underlying bidirectional structure of a sound analogy. That is, the analogy above is sound not only because the two pairs [kittens and cats] and [foals and horses] differ commonly along the dimension of age, but also because the orthogonal pairs [kittens and foals] and [cats and horses] differ commonly along the dimension of species. Note that the degrees of freedom are such that the coherence of the analogy is spoiled if either (a) any other dimension of difference is introduced to any one of the terms, for example, kittens : cats :: foals: mares, or (b) the extent of the nature of the difference on any of the linking dimensions differs between pairs, for example, kittens : cats :: foals : yearlings/nags.

To clarify the underlying logic of sound analogies, we introduced them through the format shown in Figure 6. Examining Figure 6, one sees that the picture in the top, leftmost box differs from the one to its right in both size and color; at the same time, it differs from the one beneath it only in shape. For each problem, the students are required to identify all such dimensions of change and to write them on the corresponding arrows, above and beside the analogy. The labeled arrows then provide all necessary and sufficient information for identifying the missing term: It must differ from the box beside it exactly and only in color and size; it must differ from the box above it exactly and only in shape; the missing term must be the small black triangle. Although the purpose of these exercises is to develop the student's appreciation of the logical structure of sound analogies, their success in so doing depends on whether the student actually uses the dimensional information to solve the analogies rather than, say, filling in the arrows and then independently selecting a response alternative. To encourage the former, the Unit proceeds to three-by-three analogies. Readers familiar witl Raven's (1938) *Progressive Matrices* know how befuddling such problems can be; yet, their solution is completely straightforward if one begins with an analysis of their dimensional structure (see Hunt, 1974, for a similar analysis).

[Insert Figure 6 about here.]

It is worth noting that the logically unbalanced or unsound analogy is also culturally important as perhaps our most powerful mechanism of unfounded propaganda and prejudice (e.g., I don't trust Jack because he looks like Dick). Equipping students with the knowledge and inclination to analyze analogies should serve not only to increase their creative powers but, further, to protect them from such stupidities.

Higher-order challenges. For purposes of illustrating the method through which higher-order challenges are built upon the basic processes, I have chosen to draw principally on materials from the Unit on "Word Relations" in the *Understanding Language* Series (Herrnstein, Adams, Huggins, & Starr, 1986). Because these materials are more atomistic and less adventuresome than many in the curriculum, I do so with some reluctance. It is unfortunately the case that the more complex and conceptually engaging a set of materials, the more difficult it is to develop within the page and style restrictions of a paper such as this, and I ask that the reader bear this in mind.

The first topic tackled in the Unit on "Word Relations" is synonyms or, more specifically, synonymous descriptors from orderable dimensions. The students begin by calling out words that describe size. After a number of such words have been generated, the students are challenged to order them from smallest to largest. The ordered list ends up looking something like the following:

tiny
little, small
medium, middle-size
large, big
huge, giant
tremendous, enormous, gigantic,

where words are written on the same line wherever the students have disagreed with one another about which exceeds which in meaning. The point is then drawn from the students that the closer any two words are on the list, the closer their meaning. As reinforcement, the students are given a series of problems as shown in Figure 7.

[Insert Figure 7 about here.]

The idea of relative proximity of meaning along a single, orderable dimension has considerable merit for purposes of introducing the notion of synonyms. It is concrete, it inherently captures the relativistic nature of synonymity, and it builds directly upon the basic analytic concepts and processes with which the students have already been familiarized.

On the other hand, the meanings of relatively few words can be captured by their position onto a single, orderable dimension. To the contrary, most words are like little bundles of meaning, conveying characteristics or values on many dimensions at once. To help the students recognize this fact, they are then challenged to generate an ordered list of animals.

Quickly the problem is discovered: Animals can be ordered along any number of dimensions: longevity, ferocity, speed, adult weight, furriness, length of tail, and so on. To be synonyms, the meanings of two words must be similar on every single one of their subtended dimensions. The point is reinforced through a series of problems as illustrated in Figure 8. Taking the approach one step further, grammatical function or part of speech is treated as one more dimension of a word's meaning.

[Insert Figure 8 about here.]

After synonyms, the Unit turns naturally to antonyms. If synonyms are words whose meanings are as similar as possible, then what are antonyms? Without fail, some authoritative subset of the students will announce that antonyms or opposites are words whose meanings are as different as possible, thus setting up both the lesson and their receptivity to it. Are tall and sour antonyms? Could their meanings be any more different? How about tall and red? Red and sour? In the process of suggesting and defending the proper antonyms for each such pair of words, the students themselves raise the first critical amendment to their initial definition: Two words can be antonyms only if their meanings fall on the same dimensions. Their new discovery is then extended through a series of exercises designed to help them consider the variety of dimensional contrasts that support antonymity (e.g., location, direction, quantity, reciprocity, and negation).

To elicit the second critical amendment to their initial definition of an antonym, focus is returned to the concept of orderable dimensions. With reference to the representation in Figure 9a, it is recalled that synonymous words are those that lie very close together. Requesting an analogous heuristic for antonyms yields the suggestion that they, in contrast, ought to lie as far apart as possible. Although the heuristic works well for "freezing" (Figure 9b), it fails with "cool," and the students are thus led to discover the principle of reflectivity that is illustrated in Figure 9c. For each problem in the exercise set illustrated in Figure 10, the students are given an ordered list of words and asked to determine, on the basis of this principle, the antonyms of each. Each of these problems includes at least one word that was expected to be at least somewhat ill-defined in the minds of at least some of the students. At the same time, however, each problem provides all necessary support for very precisely inferring the meanings of such less familiar words. In this way, the exercise serves at once to reinforce and to motivate the analytic processes at issue.

[Insert Figures 9 and 10 about here.]

The next two lessons in the Unit are on words and classification and can be summarized in terms of three separate subgoals. The first, which involves more or less canonical word classification exercises, is designed to sharpen the acumen and flexibility with which students can focus on one dimension of meaning versus another. The second is designed to demonstrate how class- or category-level information in a text can be used to narrow in on the meaning or significance of its unfamiliar words. And the third, developed through a short story, is intended to provide a dramatic and understandable overview of the way in which the English (Spanish) lexicon stands as a hierarchically classificatory system of knowledge representation and reference.

The last lesson in the Unit is on verbal analogy and metaphor. The lesson is built directly and rigorously upon the logic of the analogy as developed in the first lesson series, *Foundations of Reasoning*.

Like other instructional packages on verbal analogy, it includes a number of standard form problems, such as,

happy : ecstatic :: sad

(a) blissful

(b) angry

(c) miserable

(d) cry

Beyond solving the problems, however, students are required to check their solutions by rearranging the pairs, for example, happy : sad :: ecstatic : (?), and articulating the dimensions or relationships that hold the analogical pairs together.

The lesson then turns to metaphor, and the students are asked to fill in the blanks for series of problems like the following:

The president is the head of the company.
president : company :: head : *body*

Education is the key to opportunity.
education: opportunity :: key : *door*

The purpose of the exercise is to clarify that the meaning of a metaphor derives from the analogy upon which it implicitly rests. In addition, because students' answers inevitably differ from one another on many of the problems, it creates a forum for defending and discussing their alternatives in terms of the logic that supports them and the differences in the meaning they import to the sentence.

To extend the latter point, the students are given a series of problem pairs on metaphors and verbs. For each problem pair, their challenge is to write down and contrast the implicit comparisons:

(a) The idea blossomed in her mind. *like a flower*

(b) The idea festered in her mind. *like a sore*

The goal, in brief, is to convey that metaphor, in its most productive capacity, is not simply about colorful language; it is about powerful and precise language. Moreover, the communicative power of the metaphor is owed directly to the logic of sound analogy. Recall that, to be sound, the subordinate characteristics of an analogical pair must very nearly match. Yet, the salient characteristics of an idea and a flower do not inherently match. The tension is resolved by imputing the characteristics of a flower to the girl's idea.

Because the imputation of the characteristics of a predicate to its subject is a normal linguistic phenomenon, its occurrence does not depend upon any prior recognition of the metaphorical nature of the description. But even while the metaphor's affect is thus driven, its more precise and extended implicative force pivots on the logic of the underlying analogy and can be greatly enhanced through its explicit analysis. Thus, metaphor (a) above does not merely suggest that the idea matured and so do flowers. It further asserts that the idea possessed the characteristics of a flower: beginning as an unremarkable rub, it matured and unfolded, gradually and expansively taking on a delicate, natural beauty. In metaphor (b), on the other hand, the idea began hurtfully, as an insult to the normal tissue of thought; feeding on dirt and oozing malevolence, it sickened its host as it grew.

The extended importance of characteristics afforded through analogical allusion enables even greater communicative power and efficiency when the discourse is extended beyond a single sentence. This notion is developed later in the Series when attention is turned to the interpretation of fables and allegories and the literary function of stereotypes (see Adams & Bruce, 1982).

In overview, the goal of the Unit on Word Relations is twofold. On one hand, the Unit's purpose is to exploit the basic processes--dimensional analysis, simple and hierarchical classification, ordering, and analogy--as a means of helping the students to systematize their understanding of word meaning, to sharpen their receptive and generative use of words, and to gain an analytic edge on the challenge of acquiring new words. On the other hand, the Unit's purpose is to exploit the domain of lexical semantics as a means of reinforcing and extending the students' appreciation and understanding of the basic processes.

This reciprocal goal structure is, in fact, common to all of the domain-specific Units in the curriculum and a key aspect of its structure. That is, the central topic of the Units in each of the Lesson Series, save *Foundations of Reasoning*, was in some sense arbitrary. The single definitive characteristic of the problem domains addressed in these Series was that a mastery of the issues and challenges central to any of them would be, in itself, a significant step towards intellectual independence. Ancillary to this characteristic is that these issues and challenges are complex.

While the basic processes are intended to provide the starting point and leverage with respect to the sound assimilation of these complex problem domains, that is only half of the sought effect. In addition and following schema theory, it is intended that through their use in these other problem domains, the basic processes will themselves become enmeshed, with appropriate elaboration, in an increasing variety of problem types and situations. In this way, we seek to maximize the probability that they will be recalled and applied to whatever amenable challenges the students may encounter beyond the boundaries of this course.

Usability

The thrust of the course was to be conveyed through direct instruction, modeled on the Socratic Inquiry Method (Collins & Stevens, 1982), and capitalizing on structured discovery. To maximize usability, the Classroom Procedure for each lesson is presented in the form of a complete script. These scripts are *not* intended to be used verbatim. Their purpose is instead to provide a detailed and highly imaginable model of the sequence of interactive dialogue and activities through which the embedded lesson plan might be achieved. Their purpose, in other words, is to minimize the need for inservice training. They are offered as an efficient, easy-to-understand means for the teacher to build a usable schema of the intended logic and progression of the course.

The Teachers' Manual also includes several other features designed to increase the comprehensibility and usability of its lesson content. First, each lesson is prefaced with an explanation of its rationale, its objectives, and its conceptual relationship to other lessons in the curriculum. Second, the text of the Classroom Procedure for each lesson is divided into topical subsections and methodically formatted in a way that visually contrasts or sets off not only teacher queries and student responses, but also instructions to teachers, information to be written on the board, information about the exercises, and key terms. The purpose of this formatting is to give teachers an easy means of recalling the lesson plan while in class, without having to reread the script itself. By glancing at a page, teachers can easily pick out the information they need to remember where in the lesson they are, what the key points are, and where they are going next. It was our conviction that some such system of reminders-at-a-glance was a critical component of a usable curriculum: In class, teachers' attention and thought should be freed, to the extent possible, for the challenge of managing and stimulating their students.

Finally, the *Odyssey* curriculum includes within it all necessary texts, exercises, and demonstration materials (with the very occasional exception of such things as paper clips and poster board). Exercises and texts are provided in the Student Workbooks and reproduced, with correct answers, in the appropriate spots in the Teachers' Manual. Demonstration materials are bound in the Teachers' Manual.

None of this is intended to discourage teachers from extending the curriculum as they see fit. To the contrary, we strongly encourage such extensions: The greater the number of ways that the various components of the course are exercised, the greater and more lasting its impact. By providing such thorough conceptual and material support within the curriculum, we hope that we have created a base upon which even the least confident teacher will feel invited to build--to draw other materials and problem situations into the course, and to draw central components of the course into their instruction on other subjects.

Evaluation

Within the time span of the Venezuelan project, we could not ask about long-term effects of the course. We did, however, do our best to assess the immediate depth and breadth of the course's effects. In this section, I summarize the design and results of the evaluation effort but, for a more detailed discussion, you are referred to a recent article in the *American Psychologist* (Herrnstein, Nickerson, deSanchez, & Swets, 1986).

During the 1982-1983 school year, approximately half of the 100 odd lessons in the course were taught by teachers from the Venezuelan school system to about 450 seventh graders (12 classes) in barrio schools in Barquisimeto, Venezuela. The 12 experimental classes were selected in conjunction with 12 control classes, matched on school and classroom parameters and, insofar as possible, on students' ages, initial abilities, social-economic status, and so on.

To assess the impact of the course, all of the students completed a battery of tests at the beginning and end of the school year. One set of these tests, the Target Abilities Tests (TATs), was designed by us to assess students' mastery of the course material *per se*. The remainder of the battery, however, was put together with an eye toward assessing the general rather than the specific carryover of the course. That is, these tests were selected not to match specifics of the course but to provide a broad range of aptitude and achievement measures.

Three sets of standardized tests were included in the battery: the Cattell Culture Fair Test (CATTELL; Cattell & Cattell, 1961), which examines pictorially the abilities to extend series, classify, complete matrices or analogies, and establish conditions; the Otis-Lennon School Ability Test (OLSAT; Otis & Lennon, 1977), which presents a variety of word problems and is often used in the U.S. to estimate IQ; and eight achievement or General Ability Tests[2] (GATs). In addition, we collected qualitative assessments of the course from teachers, students, and supervisors and administered some less formal tests of reasoning and writing; these measures corroborated the results of the standardized tests.

As must be expected, the test scores of all students, both experimental and control, increased across the school year. However, the gain of the experimental students was significantly greater than that of the control students on each of the tests. One way of indicating the magnitude of the effects is to express the gains realized by the experimental group as a percentage of the gains realized by the control group. In these terms, the gain of the experimental group was 21% greater than the gain of the control group on the CATTELL test, 46% greater on the OLSAT, 68% greater on the GATs, and 117% greater on the TATs.

Further, in terms of the raw percentage of correct answers, the gains of the experimental students were virtually constant across initial tests scores. This was very important to us since a major goal in designing the course was to reach not just the quickest and not just the slowest, but *all* students. Finally, analyses of the data revealed large differences in teacher effectiveness. This was to be expected since our teachers were not selected on the basis of teaching prowess. But the point is that even those students who took the course with the least effective teachers, significantly outgained their controls on the standardized tests. We take this as very positive feedback in our efforts to make the curriculum materials universally usable.

Conclusions

I have had three major goals in writing this paper. The first has been to argue that Chapter I students could genuinely profit from instruction on thinking and that, for maximum impact, such instruction should be *introduced* as a course in itself, separate from the regular curricula. I underscore "introduced" because, of course, the ultimate goal is to transport such thinking skills to all other curricular and extr^curricular endeavors.

My second major goal has been to discuss some of the major issues and options one ought to consider before adopting a course on thinking skills for use with any given group of students. This discussion was centered on six existing programs on thinking skills. In the interest of making the discussion concrete, I found something to criticize about each of these programs. I would like to clarify, however, that I chose these six programs for discussion because each has been used relatively extensively, with enthusiasm from students and teachers, and with its own brand of success.

Depending on a classroom's particular needs and constraints, any one of them might be a very good candidate for implementation. For a relatively quick program that serves to build confidence or to "open the door" to thinking, *CoRT* is a good choice. Given relatively homogeneous groups of students and a special interest in enhancing language arts and mathematics understanding, *Think* and *Intuitive Math* are good choices. For broad or large-scale implementation, I am less enthusiastic about *Instrumental Enrichment* because I think, relative to its typical returns, it requires an awful lot of teacher training and classroom time; on the other hand, for students who are markedly below norm, this program seems a uniquely appropriate and effective option. Finally, for Chapter I students whose performance is close to grade-level or above, both *Philosophy for Children* and *Productive Thinking* are worth considering. The first of these offers the side benefit of improving reading comprehension scores; the second seems especially effective in increasing intellectual independence.

Beyond these six programs, there are and will be many others from which to choose. My third major goal has been to persuade the reader of my belief that the field is expanding not just in number of programs but in sophistication as well. The *Odyssey* program, which is just now being published, was described as an example of the forthcoming efforts. Although it has not been formally evaluated in the United States, the results of the Venezuelan experiment are very positive. As for the others, please note: Just because I could not obtain adequate information about them for present purposes does not mean there is none or will not be more.

As these programs proliferate, I hope that the present paper will help to define some of the factors governing their appropriateness and potential effectiveness for any given group of students. I hope, moreover, that it will supply some of the motivation and justification for giving the programs serious consideration. For Chapter I students especially, the direct teaching of thinking promises to be the best institutionalizable means of developing the competencies and attitudes they need to make the most of their schooling and their lives.

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Footnotes

[1]Innovative Sciences, Inc., provided me with evaluation reports from the following public schools: Detroit Public Schools/Region Eight, Detroit, Michigan; Memphis City Schools, Memphis, Tennessee; Morris Central School, Morris, New York: Natchitoches Central High School, Natchitoches, Louisiana; Franklin Pierce School District, Tacoma, Washington; and Taos Junior High School, Taos, New Mexico.

[2]The GAT was comprised of three subtests from Guidance Testing Associates; Tests of General Ability (Manuel, 1962a); three subtests from Guidance Testing Associates' Tests of Reading (Manuel, 1962b); one from the Puerto Rican Department of Education; and one developed by our own staff to assess arithmetic skills.

Author Notes

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Table 1

Contents of Odyssey

Series and Unit Titles and Descriptions	Number of Lessons
LESSON SERIES I: FOUNDATIONS OF REASONING	
Unit 1: Observation and Classification	6
Using dimensions and characteristics to analyze and organize similarities and differences; discovering the basics of classification and hypothesis-testing.	
Unit 2: Ordering	5
Recognizing and extrapolating different types of sequences; discovering special properties of orderable dimensions.	
Unit 3: Hierarchical Classification	3
Exploring the structure and utility of classification hierarchies.	
Unit 4: Analogies: Discovering Relationships	4
Analyzing the dimensional structure of simple and complex analogies.	
Unit 5: Spatial Reasoning and Strategies	3
Developing strategies to solve problems of resource allocation via tangrams.	

Table 1 (Continued)

Series and Unit Titles and Descriptions	Number of Lessons
LESSON SERIES II: UNDERSTANDING LANGUAGE	
Unit 1: Word Relations	6
Appreciating the multidimensional nature of word meanings.	
Unit 2: The Structure of Language	5
Discovering the logic and utility of rhetorical conventions.	
Unit 3: Information and Interpretation	5
Analyzing text for explicit information, implicit information, and point of view	
LESSON SERIES III: VERBAL REASONING	
Unit 1: Assertions	10
Exploring the structure and interpretation of simple propositions.	
Unit 2: Arguments	10
Analyzing logical arguments; evaluating and constructing complex arguments.	

Table 1 (Continued)

Series and Unit Titles and Descriptions	Number of Lessons
LESSON SERIES IV: PROBLEM SOLVING	
Unit 1: Linear Representations	5
Constructing linear representations to interpret n-term series prol ;ms.	
Unit 2: Tabular Representations	4
Constructing tabular representations to solve multivariate word problems.	
Unit 3: Representations by Simulation and Enactment	4
Representing and interpreting dynamic problem spaces through simulation and enactment.	
Unit 4: Systematic Trial and Error	2
Developing systematic methods for enumerating all possible solutions; developing efficient methods for selecting among such solutions.	
Unit 5: Thinking Out the Implications	
Examining the constraints of givens and solutions for problem-solving clues.	

Table 1 (Continued)

Series and Unit Titles and Descriptions	Number of Lessons
LESSON SERIES V: DECISION MAKING	
Unit 1: Introduction to Decision Making	3
Identifying and representing alternatives; trading off outcome desirability and likelihood in selecting between alternatives.	
Unit 2: Gathering and Evaluating Information to Reduce Uncertainty	5
Appreciating the importance of being thorough in gathering information, evaluating consistency, credibility, and relevance of data.	
Unit 3: Analyzing Complex Decision Situations	2
Evaluating complex alternatives in terms of the dimensions on which they differ and the relative desirability of their characteristics on each of those dimensions.	
LESSON SERIES VI: INVENTIVE THINKING	
Unit 1: Design	9
Analyzing the designs of common objects in terms of functional dimensions; inventing designs from functional criteria.	
Unit 2: Procedures as Designs	6
Analyzing and inventing procedures in terms of the functional significance of their steps.	

Figure Captions

Figure 1. At the end of the first lesson, the students are given a series of such illustrations and asked to figure out what is wrong with each. The objectives are, first, to encourage them to exercise the process of examining a scene characteristic by characteristic and, secord, to let them demonstrate to themselves that their observational powers are not as sharp as they might be. (From Adams, Buscaglia, deSanchez, & Swets, 1976.)

Figure 2. A basic exercise illustrating the point that any collection of objects can be classified according to their similarities and differences along as many dimensions as they can be described. To facilitate the task, the students are provided with a full page duplicate of the inset at the top which they are to cut apart on the dotted lines. (From Adams, Buscaglia, deSanchez, & Swets, 1976.)

Figure 3. This problem appears midway through an exercise on hypothesis-testing. Its purpose is to reinforce the importance of positive information. The essential characteristic of tweegles is that they have feathers. (From Adams, Buscaglia, deSanchez, & Swets, 1976.)

Figure 4. Examples of the abstract exercises through which sequences are introduced. For each problem, the students are to select the next member of the sequence from the lettered alternatives and to write down whether the sequence is progressive, cyclical, or alternating. (From Adams, Buscaglia, deSanchez, & Swets, 1976.)

Figure 5. A series of problems such as that given at top illustrate that the meaning of a descriptor from orderable dimensions is always relative, presuming a standard of comparison whether or not it is stated. The last problem of the set, given at bottom, illustrates that if you are not quite sure whether the comparison you have in mind will be obvious to your audience, you'd better make it explicit. (From Adams, Buscaglia, deSanchez, & Swets, 1976.)

Figure 6. An example of the problems through which the structure of sound analogies is introduced. After the students have written the horizontal and vertical dimensions of change on the corresponding arrows, they can deductively determine the correct response alternative: it must differ from the one beside it only in color and size and from the one above it only in shape. (From Adams, Buscaglia, deSanchez, & Swets, 1976.)

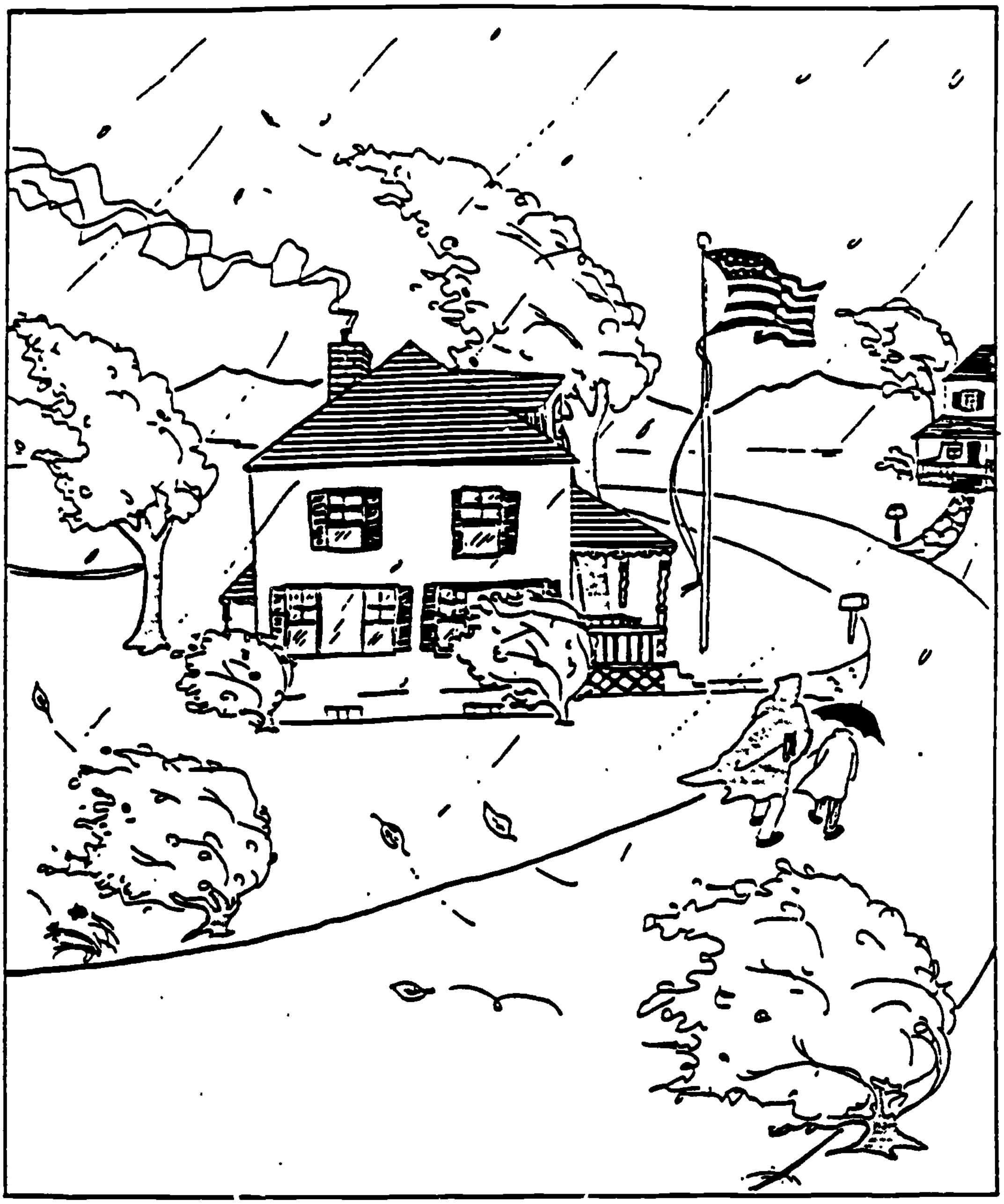
Figure 7. Examples of the problems through which the concept of synonymity is developed for words whose meanings lie on a single orderable dimension. The italicized words represent student responses. (From Herrnstein, Adams, Huggins, & Starr, 1976.)

Figure 8. The meanings of most words include characteristics from many dimensions at once. The example above is from an exercise illustrating that two such words can be synonyms only if they entail very similar characteristics on every one of their underlying dimensions of meaning. (From Herrnstein, Adams, Huggins, & Starr, 1976.)

Figure 9. In earlier lessons, analog representations such as that shown in (a) were used to support the point that the closer two words lie on an orderable dimension, the better they are as synonyms of one another. Recall of that rule leads readily to the suggestion that anonyms ought to lie as far apart from each other as possible, as shown in (b). The principle of reflectivity, shown in (c), is established through discussion. (From Herrnstein, Adams, Huggins, & Starr, 1976.)

Figure 10. The words on the left are listed in order from most positive to most negative. By applying the rule at the top, the students are to divide the list up into autonymous pairs (words in parentheses represent student responses). Note that, as long as the student is familiar with some of the words on a list, the structure of the exercise allows for the meanings of the remainder to be inferred quite precisely. (From Herrnstein, Adams, Huggins, & Starr, 1976.)

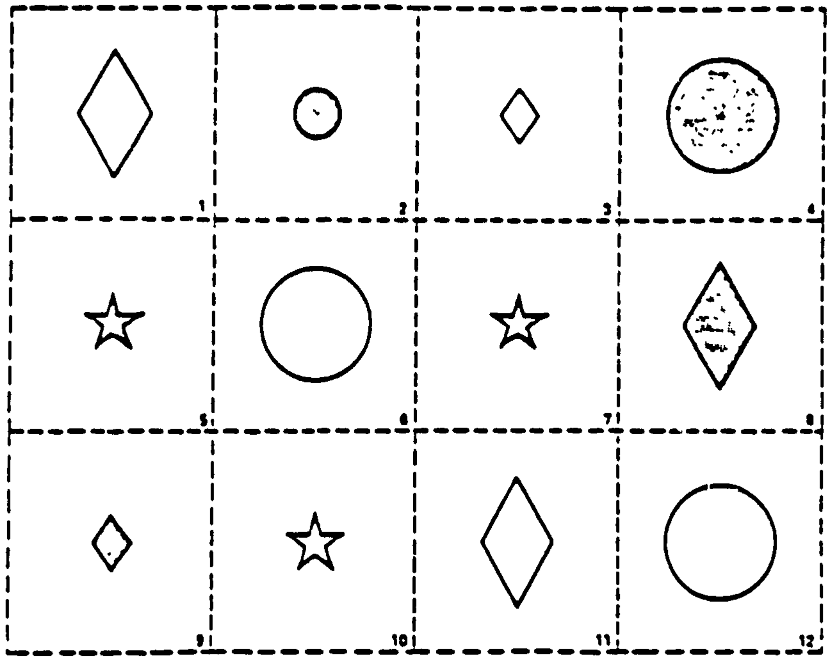
Observation



What is wrong? ______________________________

Figure 1

Classification



1. Dimension = Color

   Class 1: ____________ Class 2: ____________

2. Dimension = Shape

   Class 1: ____________ Class 2: ____________

   Class 3: ____________

3. Dimension = Size

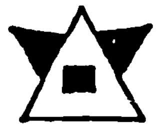
   Class 1: ____________ Class 2: ____________

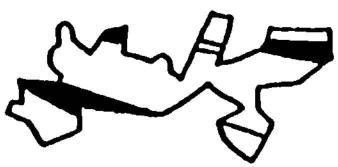
Figure 2

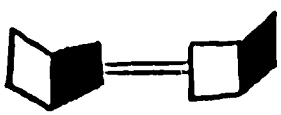
Hypothesis Testing

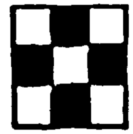
Exercise Four:

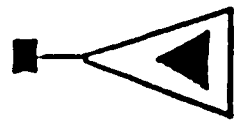
1. This is <u>not</u> a tweegle. 

2. This is <u>not</u> a tweegle. 

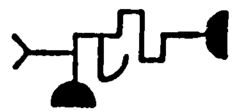
3. This is <u>not</u> a tweegle. 

4. This is <u>not</u> a tweegle. 

5. This is <u>not</u> a tweegle. 

6. Could this be a tweegle? _____ 

7. Could this be a tweegle? _____ 

8. Could this be a tweegle? _____ 

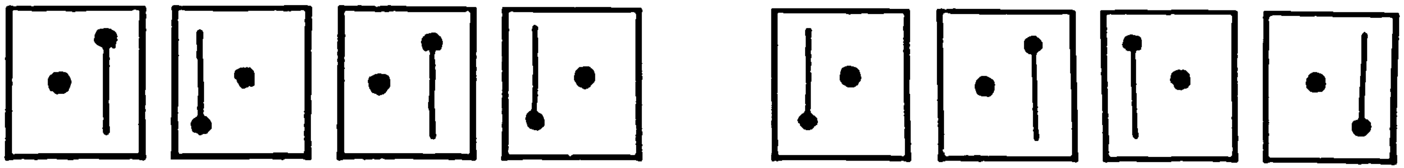
9. Could this be a tweegle? _____ 

Essential Characteristic: ____________________________________

Figure 3

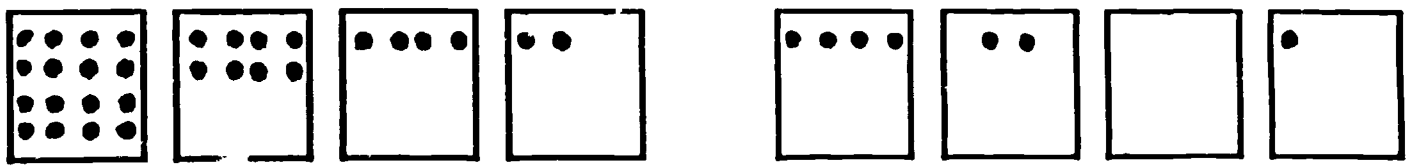
Sequences and Change

Figure 4

1. 

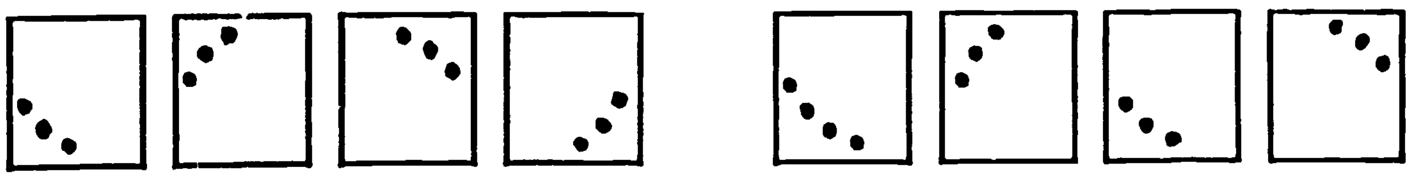
A) B) C) D)

Type of Change: ____________________

2. 

A) B) C) D)

Type of Change: ____________________

3. 

A) B) C) D)

Type of Change: ____________________

"Monkeys are exceptionally intelligent."

The author probably means:

a) Monkeys are exceptionally intelligent compared to Albert Einstein.

b) Monkeys are exceptionally intelligent compared to other animals.

c) Monkeys are exceptionally intelligent compared to rocks.

"A bripala is very expensive."

The author probably means:

a) A bripala is expensive compared to a blouse.

b) A bripala is expensive compared to a diamond.

c) A bripala is expensive compared to a sandwich.

Figure 5

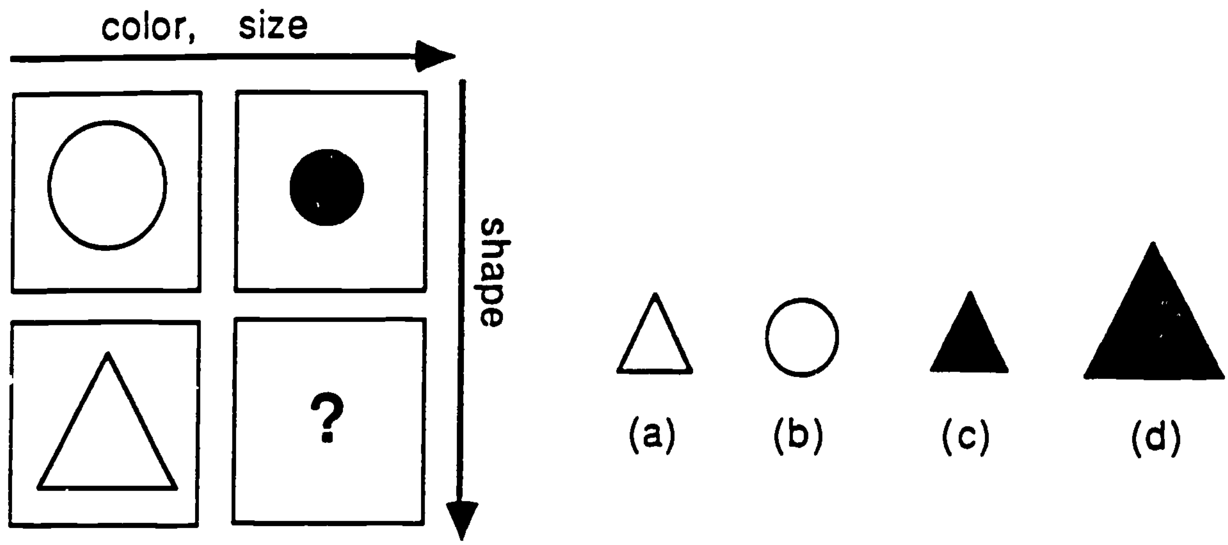


Figure 6

Synonyms from Orderable Dimensions

Instructions: Each line on the right represents an orderable dimension. Order the words in the list by writing each one beside one of the dots on the line. Then find the best synonym for the underlined word in the sentence and write it in the space provided.

Set 1:

1. hot
   icy
   boiling
   cool
   scalding
   cold
   warm
   frozen

icy — frozen
cold
cool
warm
hot
scalding
boiling

They burned their mouths on the <u>boiling</u> tea.

Synonym for <u>boiling</u>: scalding

2. often
   always
   rarely
   frequently
   occasionally
   never

never
rarely
occasionally
frequently
often
always

The nurse stated that children should bathe <u>often</u>.

Synonym for <u>often</u>: frequently

2

Figure 7

Not Quite Synonyms

Instructions: Match each pair of words to the description of the difference in their meaning. Write the letter that identifies the description in the blank beside the word pair.

1. ____ jail - cage

   ____ petite - puny

   ____ pig - pork

   ____ boulder - pebble

a) Both are rocks, but the first is very big while the second is very small.

b) The first is for locking up people, while the second is for locking up animals.

c) Both mean small, but the first is kind while the second is insulting.

d) It's the same animal, but you use the first word when it's running around and the second when you're going to eat it.

Figure 8

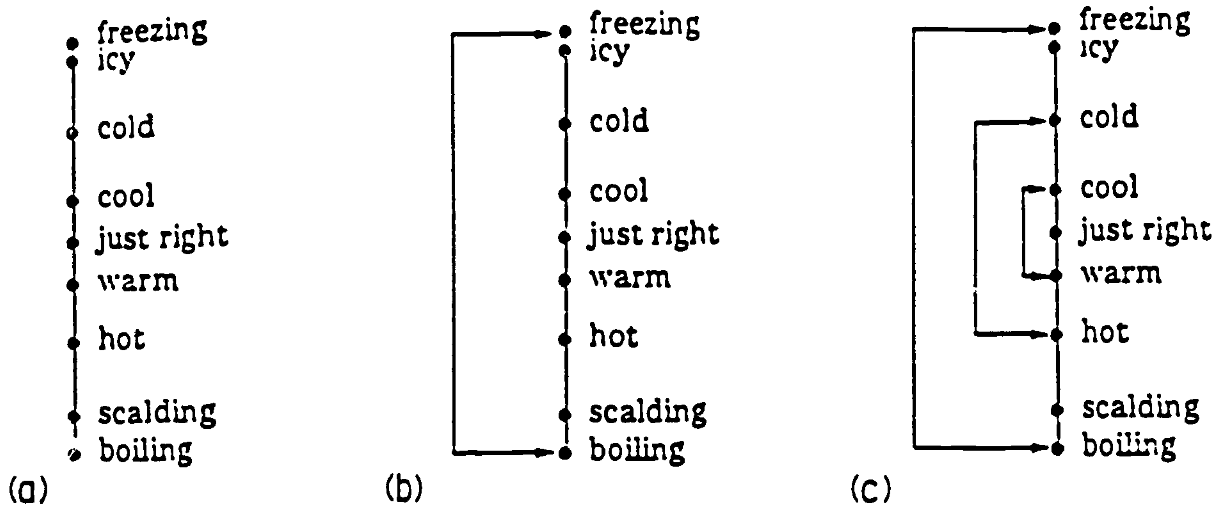

freezing
icy
cold
cool
just right
warm
hot
scalding
boiling
(a)
(b)
(c)

Figure 9

Antonym Rule

Two words from an orderable dimension are antonyms if they lie

1. on opposite sides of the middle of the dimension, and
2. the same distance from the middle of the dimension.

1. adore	adore - *(abhor)* .
love	
like	*(love)* - hate
dislike	
hate	like - *(dislike)* .
abhor	

- - - - - - - - - - - - - - - - - - - -

11. exalt	exalt - *(condemn)*
laud	
praise	*(laud)* - censure
approve	
disapprove	praise - *(rebuke)* .
rebuke	
censure	*(approve)* - disapprove
condemn	

Figure 10