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ABSTRACT

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DESIGNING INSTRUCTION IN READING: INTERACTION OF THEORY AND PRACTICE

Lauren B. Resnick and Isabel L. Beck

Learning Research and Development Center

University of Pittsburgh

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Abstract

The role of information-processing task analysis in linking psychological theory to instructional practice is illustrated with reference to reading. Two detailed information-processing models of decoding skills are compared to show how psychological considerations suggest the superiority of one model over the other as a basis for instruction. Procedures for teaching the superior model are examined and related to general principles of instructional design, and examples of research questions generated by instructional practice are discussed. A final section considers the role of task analysis in bringing psychological theory to bear on instruction in the complex skill of reading comprehension. A general map of the domain of reading comprehension is proposed and consideration given its implications for both research and instruction.

DESIGNING INSTRUCTION IN READING: INTERACTION OF THEORY AND PRACTICE

Lauren B. Resnick and Isabel L. Beck

Learning Research and Development Center
University of Pittsburgh

This paper is about reading. It is also, more generally, about instructional design strategies and about the relationship between psychological theory and its applications in education. A common conception concerning this relationship between theory and practice is that there exists a linear, one-way communication. According to this view, scientists offer their knowledge and principles for others to apply, but they continue to draw their research questions almost exclusively from within the "basic" science community. We take a different point of view here. We consider it to be more fruitful for both parties if application and science maintain an interactive communication, a communication in which scientists direct their attention, in part, to questions which are posed by social needs and in which application experts--in the present case, instructional designers--become active partners in the generation and testing of theory. (See Resnick, 1975, for a more general discussion of the relationship between basic science and instructional design.)

As colleagues, we represent personally the kind of interaction about which we are speaking. We are a psychologist (Resnick) and a reading specialist (Beck) who work in a unique institutional environment (the Learning Research and Development Center at the University of Pittsburgh) that not only accepts, but also actively encourages collaboration across disciplinary boundaries. In this paper, we will refer extensively to a primary grade reading program whose development, under Beck's direction,

exemplifies the kind of interaction between scientists and practitioners, psychologists and instructional designers, that we would like to see become more widespread.[1] During our discussion, we allude to certain segments of the program but make no attempt to describe it fully. Rather, we describe particular portions of the program that help to illustrate the points we are making about the content and form of early reading instruction and their relation to an emerging theory of instruction.

The term instruction is used here in its most general sense. It refers to any set of environmental conditions deliberately arranged to foster increases in competence. Thus, instruction includes demonstrating, telling, and explaining, but it also includes physical arrangements, the structure of presented material, sequences of task demands, and responses to the learner's actions. A theory of instruction must concern itself with the relationship between any modifications in the learning environment and the resultant changes in competence. When we are concerned with intellectual competence, developing a theory of instruction requires a means of describing states of intellectual competence in psychological terms and, ultimately, a means of relating manipulations of the learning environment to changes in these states.

Task analysis plays a central role in the development of a theory of instruction for intellectual or "cognitive" domains such as reading. By

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[1] The program is designed to teach reading in a primary school environment that is committed to adaptation to individual differences. The early portions of the program have been used in trial versions with several hundred kindergarten and first-grade children. Tests of the more advanced levels are now underway. The program is a complex one, using multiple resources--teacher and cassette-led instruction, self-instructional materials, games, free reading activities, and the like. (See Beck & Mitroff, 1972, for a full rationale and description of the system.)

task analysis we mean the translation of subject-matter descriptions into psychological descriptions that take into account such basic psychological processes as attention, perception, memory, and linguistic processing. Such analysis links the complex tasks of education to the constructs developed in the laboratory and provides psychologically sound descriptions of the content of instruction. With the content thus described, it becomes possible to apply psychological principles of learning and performance to the design of interventions that will facilitate the acquisition of competence, and the maintenance of desirable levels of performance.

In this paper, we attempt to illustrate the role of information-processing task analysis in linking psychological theory to instructional practice. We begin by focusing on a limited part of the reading domain--decoding. We propose a pair of detailed information-processing models of word attack behavior and show how psychological considerations suggest the superiority of one model over the other as a basis for instruction. We then examine actual instructional procedures for teaching the model selected, and we relate these procedures to certain general principles of instructional design. We also discuss research questions that are stimulated by the existence of instructional programs, thus completing the communication cycle between practice and science.

In a later section, we consider the kinds of analyses that will be needed to bring psychological theory to bear on instruction in the complex skills of reading comprehension. We propose a general psychological "map" of reading comprehension and consider what it implies for reading instruction. Throughout this paper we draw attention to the problem-solving nature of reading behavior, particularly its characteristic successive reduction of uncertainty, and to the implications of this analysis for both instruction and research in reading.

Initial Reading

Choosing A Basic Approach

Over the years there has been substantial debate concerning appropriate strategies for initial reading instruction. Without reviewing the "great debate" (see Chall, 1967) over decoding approaches as opposed to "whole word" approaches to reading, it may be useful to point out a set of hidden assumptions that underlies the differences of opinion. Proponents of various whole word approaches--basal reading, language experience, and so on--usually assume that good initial reading should match skilled reading performance as closely as possible. In other words, since skilled readers process units such as words and sentences, so should beginning readers, even if they can manage only a few words and sentences. Similarly, since skilled readers interpret and apply what they are reading, so should beginning readers. By contrast, a decoding emphasis in early reading assumes that the initial job is to learn the most generative form of the reading process--a form that is relatively easy to learn and that allows the learner to later approximate the performance of skilled readers.

We adopt here a code-breaking approach to initial reading. In doing so we agree with the large majority of scholars--both psychologists and linguists--who argue that a fundamental task of initial reading is learning the structural relationships between written and spoken language, that is, the grapheme-phoneme mapping that characterizes the language (see Chall, 1967; Diederich, 1973). While virtually all scholars concerned with reading now agree that early and regular instruction in some type of code breaking is needed, there still exist competing theories about how code breaking itself should be taught. There are two major approaches, the analytic and the synthetic. The analytic approach attempts to teach grapheme-phoneme correspondences to the child by having her examine displays of

words that share and contrast major spelling patterns. The synthetic approach teaches grapheme-phoneme correspondences directly by having the child assemble words from phonemes. The main point of difference between the two approaches concerns whether learners should ever be asked to pronounce individual phonemes outside of the auditory context of the entire word. Proponents of the analytic approach argue that since isolated phonemes do not occur in natural speech, the blending process of the synthetic approach unnecessarily and unnaturally burdens the child and magnifies the difficulties of the learning task.

The analytic method of teaching decoding may indeed avoid the problem of pronouncing isolated phonemes and of blending them. However, it introduces another problem which may be even more difficult for the child. Analytic decoding methods do not eliminate the need to abstract phonemes from the speech stream; in fact, they require that the child independently extract the phonemes. This detection of phonemes requires quite extensive skills in auditory analysis and in general concept attainment strategy. For at least some children these demands are too great. By contrast, the synthetic approach provides direct help by indicating the units with which the child must deal. The child's attention is directed to the grapheme, and the phoneme is sounded, she need not discover the relationship independently. Furthermore, a natural feedback system is inherent in the process. Since phonemes do indeed normally occur in the environment of other phonemes rather than in isolation, the child can test her own verbal production (the result of blending) against what "sounds right." For example, having blended /k/ /a/ /t/ to produce cat, she can test to see whether she has pronounced a word that is in her aural vocabulary.

For these general reasons, we favor a synthetic approach to decoding instruction. However, since one of the primary pedagogic objections to this approach has been the difficulty of learning the process of blending, we have sought a means of simplifying and making more explicit the process of

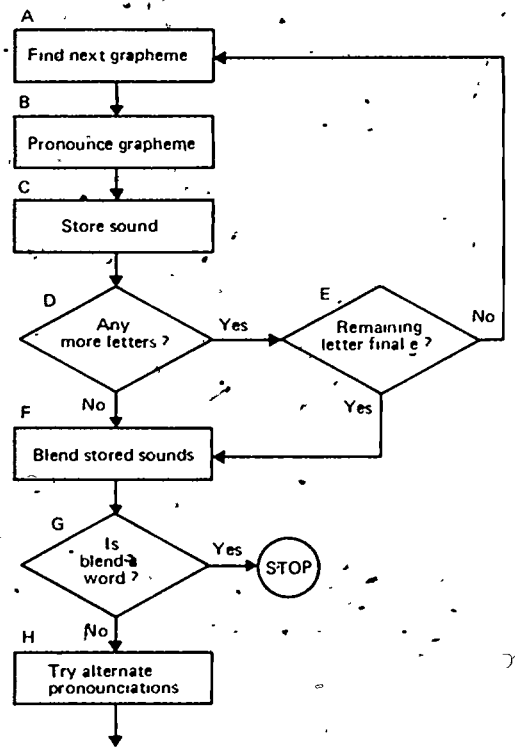
putting sounds together. For this purpose, we have analyzed two possible strategies of blending, one commonly used in initial teaching, and one we developed while working with children who were having difficulty in learning to read.

Analysis of the Decoding Process

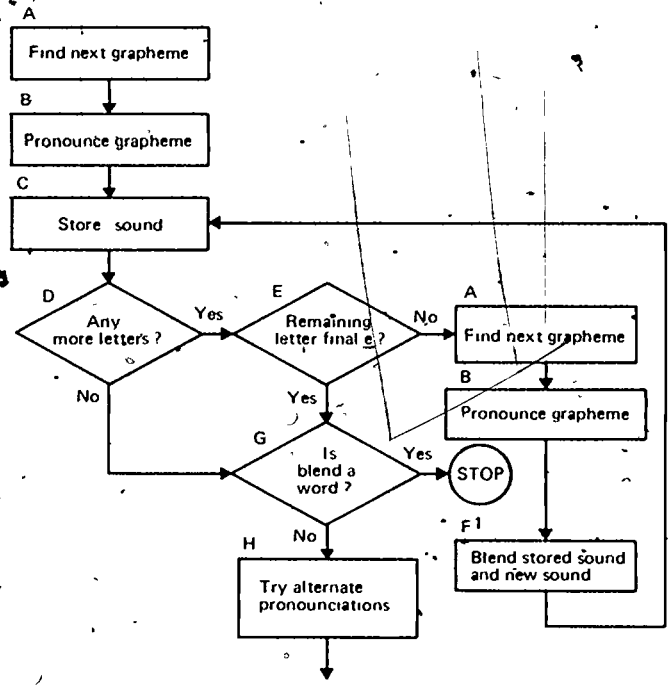
Two blending procedures. Figure 1 shows the general structure of the two blending routines we examined. In each case, the routine is capable of decoding single-syllable, regularly spelled words--the typical vocabulary of a beginning phonics program. At the left (Figure 1a), the procedure is one in which the sound of each grapheme is given and stored; the synthesis occurs only after the final phoneme has been pronounced. We call this the "final blending procedure, since blending is postponed until the very last step. Figure 1b, at the right, shows a procedure for successive blending. As soon as two sounds are produced, they are blended, and successive phonemes are incorporated in the blend as they are pronounced.

The final blending and successive blending routines can be thought of as different "executive programs" that call upon the same set of decisions and actions. finding graphemes in sequence (Component A), pronouncing identified graphemes (Component B), storing (remembering) pronounced sounds (Component C), deciding whether more graphemes remain to be sounded (Components D and E), blending (Component F), and, finally, in each case, matching the produced word against one's linguistic knowledge to determine whether the word generated is an acceptable decoding. The two routines differ only in the organization of these components, a difference that appears to have important consequences for the ease of learning and performing the decoding act.

To illustrate the differences between the two blending routines, let us use the word cats as an example and analyze the exact respects in which



1a Executive for final blending procedure



1b Executive for sucessive blending procedure

Figure 1 Executive routines for synthetic decoding

the two routines differ. The child who uses the final blending routine would proceed as follows: /k/ /a/ /t/ /s/ cats. The child who uses the second system would proceed thus: /k/ /a/ /ka/ /t/ /kat/ /s/ /kats/ cats.

Consider the contrast between the two procedures. In the final blending routine, each grapheme's sound is given, and the full set of phonemes in the word must be held in memory until the entire word has been "sounded out"; only then does blending occur. But in the successive blending routine, blending occurs sequentially, at each stage at which a new phoneme is pronounced. At no time must more than two sounds be held in memory (the sound immediately produced and the one that directly precedes it) and at no time must more than two sound units be blended. Thus, the routines differ in two respects: (a) the maximum number of sound units to be held in memory during decoding and (b) the maximum number of units to be blended. The standard routine at the left of Figure 1 requires remembering each of the separate units that the reader identifies as graphemes. The routine on the right never requires remembering more than two units.

It would seem, at first glance, that while the two routines might produce different levels of difficulty for the pronunciation of long or complex words, they would be about equally difficult for the shorter words (usually no more than three of four graphemes) that compose the beginning reading vocabulary of any phonically oriented instruction. After all, first-grade children normally have a memory span that can easily encompass three elements (as shown, for example, by the digit span test of the Stanford-Binet, which expects memory of three digits at age 3; five at age 7).

Tests such as the digit span, however, require only that items be held in memory. Items need not be generated, and no competing processing interferes with retention. This, however, is not the case during decoding. A substantial amount of other processing must occur simultaneously with the retention of phoneme elements. Assuming a limited working space or

"working memory" (as is common in virtually all current information-processing theories), this additional processing is likely to interfere with remembering the sounds, or rehearsal of the sounds may interfere with other processing (see Baddeley & Hitch, 1974; Posner & Rossman, 1965). In either case, decoding may not succeed.

The Find Next Grapheme subroutine. The complexity of the competing processing tasks can best be appreciated by considering some of the subroutines in the two blending procedures. Figure 2 shows an analysis for the subroutine Find Next Grapheme (Subroutine A). This subroutine is required because of a small but significant number of cases in which graphemes consist of pairs of letters that carry a single sound. Such graphemes are digraphs (e.g., <ch>, <ea> or diphthongs (e.g., <oy>). If the reader neglects to look ahead in order to detect the presence of a digraph or a diphthong, then she cannot correctly decode the word. The reader must first find the leftmost letter not yet sounded (A1). If more letters remain (A2), she finds the succeeding letter (A3). Embedded in these simple statements, but not explicitly shown as subroutines, is a complex set of requirements which involves maintaining left-to-right encoding during reading and keeping track spatially of one's position within a word and within a line of text. This spatial information must be maintained despite the interruptions of sounding. Thus, these simple steps place considerable demands upon a beginning reader, demands that compete for processing space with the retention of the sounded-out phonemes.

Having focused upon two successive letters, the reader must decide whether they form a single digraph or a diphthong (A4). This decision assumes that the individual has in long-term memory a list of digraphs and diphthongs with which the current letter sequence is matched. Presumably, this list is gradually compiled during the course of learning to read and becomes longer and longer as the acquisition of reading ability progresses. If two letters form a digraph or diphthong, they are classified jointly as a

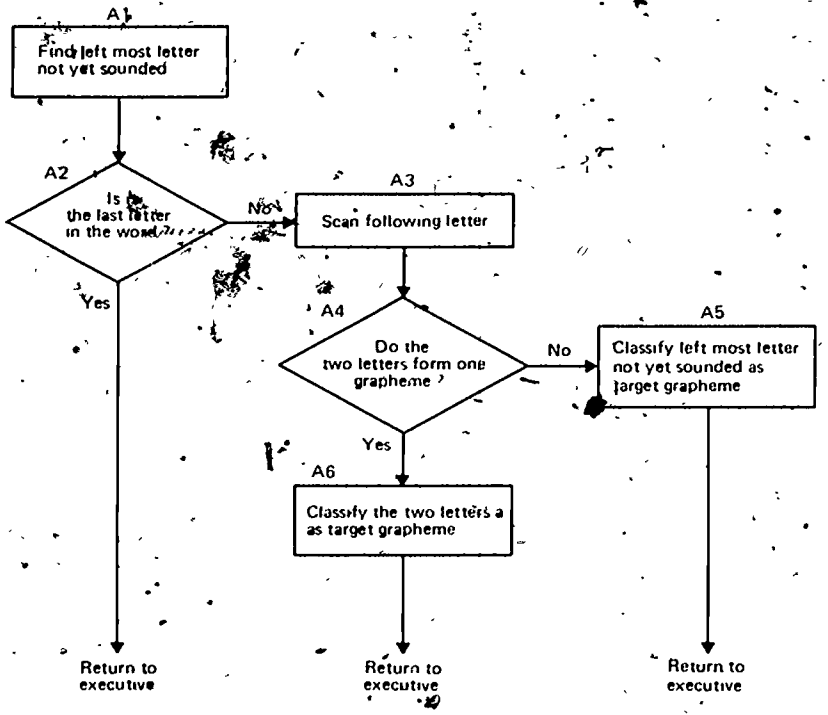


Figure 2. Subroutine for Find Next Grapheme

grapheme (called the 'target grapheme' in the analyses) at A6, and control of behavior is now returned to the executive program (Figure 1). If the two letters do not form a single grapheme, attention is returned to the first letter identified in the subroutine, and that letter is classified as the target grapheme (A5). Control is then returned to the executive. The return of control signifies completion of the subroutine, the executive will now move to the next subroutine indicated. In both the final blending and the successive blending executives, the next subroutine is Pronounce Grapheme (Subroutine B of Figure 1).

The Pronounce Grapheme subroutine. Figure 3 shows the subroutine for the pronunciation of graphemes. This subroutine assumes that a target grapheme has been identified. The pronunciation routine depends upon whether the target grapheme is a consonant or a vowel unit (B1). If it is a consonant, the grapheme must be matched against a stored list that classifies consonants as variant or invariant in pronunciation (B2). If it is variant (e.g., the letter c), the next letter is scanned (B3) for information regarding the appropriate pronunciation of the target (e.g., hard sound if an a follows, soft sound if an i follows). On the basis of the next letter, the target grapheme is pronounced (B4). Control then returns, as it does after any pronunciation, to the executive program. If the target grapheme is classified as a vowel (B5), it can be either a single vowel (B6) or a vowel digraph or diphthong. If it is a digraph or diphthong, then that vowel combination is pronounced (B7) without further scanning, since the succeeding context will not typically determine pronunciation in regular words. If the target is a single vowel, the decoder looks at the remaining letters (B8) and decides whether the remaining letters are all consonants (B9) (e.g., <nt> in ant, or tch> in stretch). If so, then the target grapheme is pronounced with the short vowel sound (B10). If the remaining letters are not

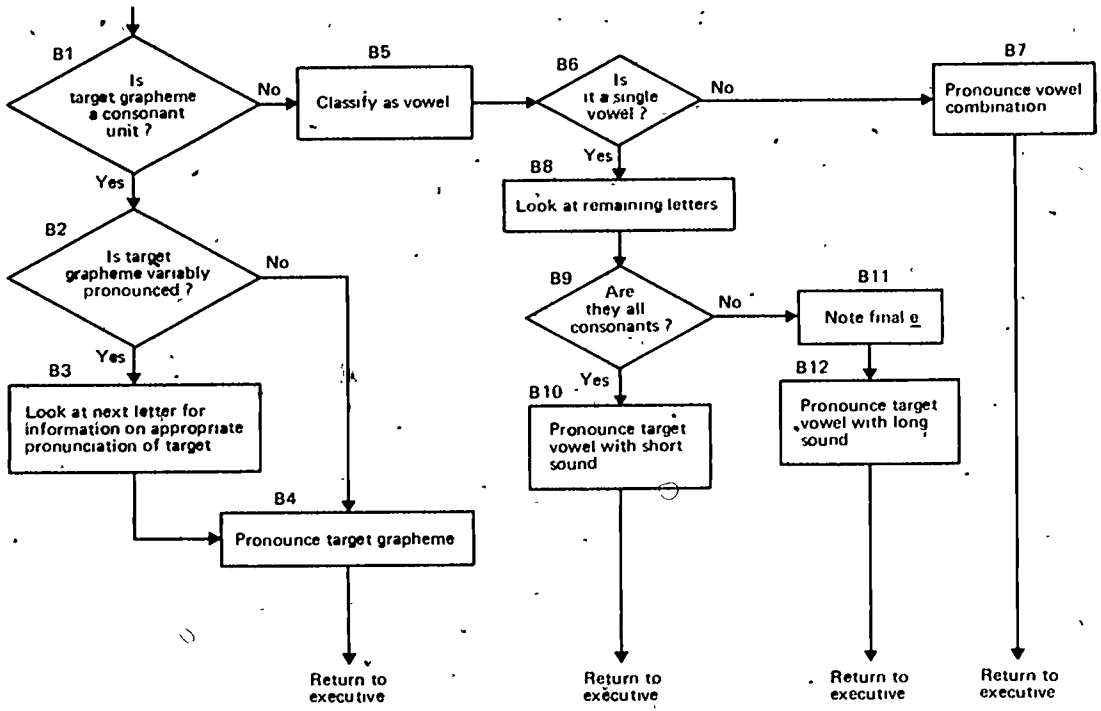


Figure 3. Subroutine for Pronounce Grapheme

all consonants, the decoder notes the final e (B11), which is the only non-consonant ending possible in regular single syllable words, and the target vowel is pronounced with the long vowel sound (B12).

The Pronounce Grapheme subroutine will succeed in a large, but nevertheless limited, set of word environments. It assumes single syllable words, with regular grapheme-phoneme mappings. The routine would have to be expanded substantially to cope with certain words with very unusual grapheme-phoneme structures. Nevertheless, the basic patterns of decisions and classifications, based upon scanning the surrounding graphemic context, would undoubtedly characterize such an expanded routine. A further point is important to keep in mind: The subroutine for pronouncing graphemes does not--cannot in English--guarantee a correct pronunciation. It provides only a workable routine for generating a candidate pronunciation, a pronunciation that, upon return to the executive routine, must be tested in order to determine if a recognizable word has been generated. If the candidate pronunciation does not produce a recognizable word, alternate pronunciations will be tried. Thus, the total program, including executive and subroutines, can be characterized as a generate-and-test program, a type of program that is heuristic in nature and that iteratively gathers and organizes information.

The Task Analyses as Routines for Instruction

The task analyses just presented can be thought of as detailed hypotheses that will be effective in instruction. Several criteria that are relevant in selecting such routines can be derived from a general consideration of the relationship between the structure of a task as defined by the subject matter, the ease with which particular routines can be learned or taught, and the performance of skilled individuals on a task (see Resnick, in press). To put the case in its most general form, it would seem useful to think of

a "triangulation" relationship between task structure, initial acquisition of a skill, and skilled performance. This relationship is schematized in Figure 4. As suggested by the figure, a good instructional routine must be clearly related to the structure of the subject matter (the A-B relationship). The instructional routine, once acquired, must also put the learner in a position to move to more skilled or fluent performance such as characterizes skilled individuals (the B-C relationship). Skilled performance, in turn, will also reflect the structure of the subject matter, but at a different level; it will include efficiencies based on the elimination of redundant steps, the use of larger units of information, and so forth. This set of relationships suggests the following criteria for a good instructional routine:

1. The routine must embody a good <u>representation of the subject matter structure</u>.
2. The routine must be <u>teachable</u> with relative ease.
3. The routine as taught must be <u>transformable</u> into the more efficient routines of the skilled individual.

Let us elaborate somewhat on each of these criteria, suggesting how the present analyses meet them and describing how the analyses have influenced instructional decisions.

<u>Representation of subject matter</u>. The Decoding routines discussed earlier represent grapheme-phoneme correspondences (the subject matter) in the form of an "idealized" performance. The routines include a representation of the grapheme structure, as opposed to single-letter structure, of English (as in the Find Next Grapheme subroutine). They show how the surrounding graphemic context affects pronunciation of any single grapheme (in the Pronounce Grapheme subroutine). In fact, the explicitness of these representations suggests quite strongly the order in which specific symbol/sound correspondences should be introduced in instruction. This is a central decision in the design of any decoding-oriented program. Two criteria

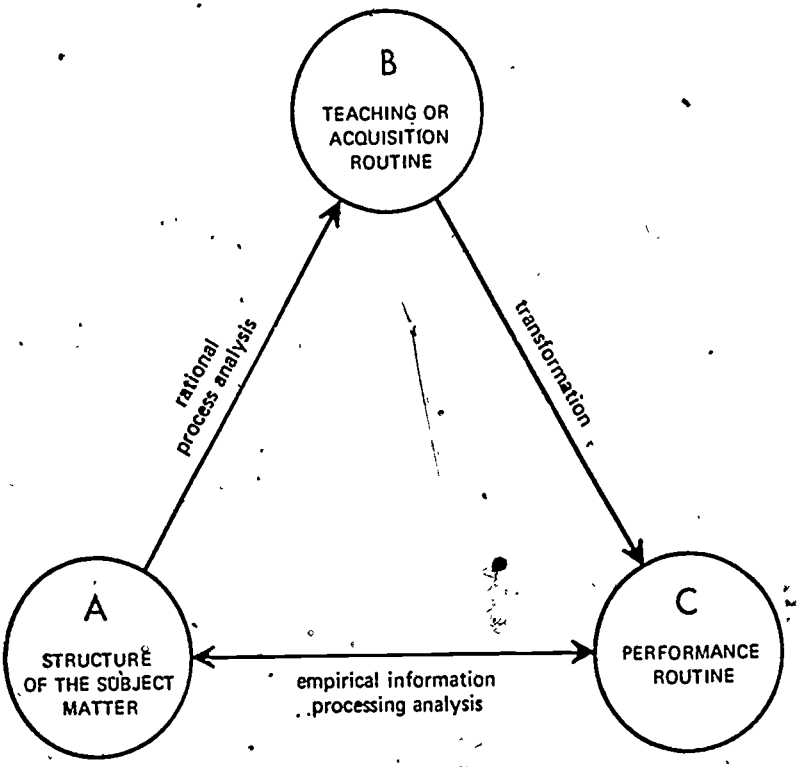


Figure 4. Relations between teaching routines, performance routines, and structure of subject matter

are traditionally used. (a) the ease with which a given symbol/sound correspondence can be learned, and (b) the utility of a grapheme, in conjunction with other graphemes, in generating meaningful and possibly pictureable words. The first criterion in particular suggests that highly "regular" and simple graphemes should dominate the early phases of instruction. This would usually mean invariantly pronounced consonants and only a single, usually the short, vowel sound. It would also mean single letters as opposed to digraphs. The analyses of the Find Next Grapheme and Pronounce Grapheme subroutines (Figures 2 and 3) suggest, however, that this strategy may hinder a child's subsequent reading progress by discouraging scanning ahead to identify graphemes and their pronunciations, behavior that is characteristic to both routines. In our curriculum, therefore, examples of consonant and vowel digraphs are included early in the graphemic sequence, as are both short and long single vowel pronunciation patterns. Thus, even when exposed to a relatively limited and regularly patterned corpus of words, the child learns that reading involves a searching ahead for information and that it cannot be performed as merely a chain of responses.

Teachability. Our comparison of the final and successive blending procedures, we believe, strongly suggests the advantages of the latter procedure. The advantage of successive blending lies essentially in the reduction of memory load, which for many children may make the difference between a learnable and an unlearnable word attack routine. For this reason we systematically teach the successive blending routine in our program.

Transformability. Skilled readers do not often go through a decoding process as detailed as the one we have shown. They do not usually read in letter or graphemic units. In fact, the speed at which normal skilled reading occurs suggests that for much reading there may not be a full intervening translation into an auditory form. Even when they encounter difficult words, skilled readers are likely to analyze the words in terms of syllabic or morphemic units rather than graphemes.

Although the units change, it seems reasonable to suggest that the basic flow of generating and combining sounds is probably the same for advanced as for beginning readers. It would be simple, for example, to rewrite Figure 1, substituting the more general term unit for grapheme and letter. Thus, subroutine A would read Find Next Unit, B would read Pronounce Unit, D would read Any More Units? Storing sounds, blending them, and testing them against aural vocabulary would proceed much as shown in Figure 1. The emergence of larger units need not be left wholly to chance. Several instructional strategies can assist learners in early expansion of their units of analysis. One strategy is to use spelling pattern and syllable recognition exercises. A second is the gradual buildup of a demand for faster reading, thus encouraging children to process in larger, and therefore fewer, units. A third is an early focus upon reading for comprehension, even of very simple, single line texts, so that the child's attention is focused on finding units that cue meaning. All of these techniques are woven into the earliest segments of our program.

Development of a large and easily accessed word recognition vocabulary is crucial to the eventual evolution of reading fluency. To encourage this development, explicit attention is paid in our program to moving words that have been initially learned through sounding and blending into a recognition vocabulary. Immediately after a new phonemic element has been learned, words containing that element are used in the texts with special frequency. This high frequency of occurrence leads most children to recognize the words without using any word attack routines. A few children need special help in building recognition vocabulary, and this is offered via games and additional simple texts.

Testing the Validity of Instructional Hypotheses

We have said that the analyses presented here constitute hypotheses, expressed as information-processing routines, for effective instruction.

How would one go about testing these hypotheses, thus validating the routines for instructional use?

We have already tried to show that the routines presented embody a reasonable representation of the grapheme-phoneme correspondences that constitute the subject matter of initial reading. Thus, the first criterion for a good instructional routine (see p. 14) has been met--at least to the degree that our earlier discussion has been convincing. The next requirement for validation would be to establish the teachability of the routines (our second criterion) by teaching them to a variety of different kinds of learners. The third criterion for an effective instructional routine requires that it be transformable into a more skilled and automatic performance. This criterion demands a more complex approach to validation, combining controlled instruction in decoding with systematic observation and simulation of decoding behavior of individuals over time. The strategy we propose includes the following steps:

1. Teach the hypothesized routines in a highly controlled way to insure that the routines used by the child at the outset of instruction are the ones shown in our analyses. As part of this instruction, we would require overt performance of the decoding routines. Simultaneously, write computer simulation programs for the hypothesized instructional routines. At this stage, we would expect a close match between computer outputs in reading words and the performance of children in the instructional program. That is, they should make similar errors, and, to the extent they are measurable, require similar latencies.

2. Gradually loosen our demands on the child for overt decoding performance in order to allow the transformation process to take place; that is, allow larger units and direct word recognition to emerge. As these transformations occur, we would expect the match between the computer's

and the child's performance to decline, since the computer would still be performing the initial instructional routine.

3. Next, attempt to vary parameters of the simulation programs in an attempt to regain the match between human and program performance, preferably for individual children. We might, for example, introduce a larger number of possible pronunciations for certain graphemes. We might change the "unit" of decoding from graphemes to spelling patterns (e.g., -ing, -ate, etc.). We might put into the model a larger aural recognition vocabulary or a larger sight recognition word list. The aim of this model adjustment would be to produce as detailed a description of performance at different stages of the learning process as possible.

A research program of this kind would involve a series of tests of reading models based on reading instruction of a particular kind. We believe the simulation models can be built, although we do not yet have them in running (i.e., "sufficient") form. We do already have, however, the controlled teaching strategies required.

The Instructional Strategies

We can describe briefly these instructional strategies, in order to convey their flavor and to suggest the likelihood that children experiencing them will indeed learn the routines taught. We will describe two of the initial teaching strategies included in our program. Each is designed for teacher-led small group instruction and uses a series of steps to guide the child from imitation of the teacher to independent performance.

Teaching the grapheme/phoneme correspondences.[2] In this sequence, teachers give simple, direct statements to children and fade prompts

[2] The material in this section is taken directly, with minor stylistic changes, from Beck and Mitroff (1972, pp. 44-45).

deliberately and systematically. Techniques for teaching symbol/sound correspondences are as follows:

1. The teacher models the isolated sound.
2. The children imitate the model.
3. The teacher models the sound again, this time pointing to the symbol (the letter on a printed card).
4. The children imitate the model sound, while looking at the symbol. Concurrent with the children's imitation, the teacher mouths the sound silently. In doing this, the teacher consciously establishes a cue or prompt.
5. The children produce the sound to match the symbol, without the spoken model, but with the silent mouthing cue.
6. The teacher fades the silent mouthing cue as the children produce the sound.
7. The children produce the symbol/sound correspondence independently.

Compare the directness of the above with the indirectness and miscueing of the following procedure, observed in a traditional classroom of an experienced teacher. The teacher held up a card with m printed on it and said, "This is an m. The name of the letter is m but the sound is /m/, as in 'mmmmountain.' I want to hear everyone say it." One child said em, two said /m/, another said "mmmmountain." The teacher said, "No, I want you to say the sound. Listen. /m/ as in 'mmmmountain,' 'mmmmother,' 'mmmmonkey.' Who can think of another /m/ word?" Hands went up. One child said, " 'Mmary' like my name." Teacher: "Good, Mmary. Any others?" A second child said, "We went to the mountains once. It was our vacation and we slept in a tent." With so many concepts floating about, only the most sophisticated child could extract the relevant information from the lesson. Training in the techniques of programmed teaching as described above can enable a teacher to instruct children in the basic skills with more precision.

Teaching blending. Once five symbol/sound correspondences are established, they are immediately used to blend real words. A precise

program for teaching the blending routine has been prepared for this purpose. You will perhaps have noted that our task analyses did not include a detailed subroutine for blending. This is because we know of no reasonably elaborated theory for how humans manage to recognize the equivalence of the single sound (e.g., /ka/) and the separate phonemes (e.g., /k/ and /a/). We know only that the equivalence is a difficult one and that the ability to recognize it, and therefore produce a blend, becomes greater with greater experience. In the absence of a strong hypothesis concerning the cognitive processes involved, a visual/motor analogue of the blending operation helps to organize the process for the child. We have therefore developed a somewhat ritualized blending procedure in which motor acts accompany the oral blending. These motor acts provide an external representation of what goes on during the blending process.

For example, for the word cat, the child performing the blending procedure independently would:

Point to the c and say /k/.
Point to the a and say /a/.
Slowly slide her finger under the ca and say /ka/ slowly.
Quickly slide her finger under the ca and say /ka/ quickly.
Point to the t and say /t/.
Slowly slide her finger under cat and say /kat/ slowly.
Circle the word with her finger and say, "The word is cat."

The techniques for teaching the blending procedure include steps that lead the child from imitating the procedure toward performing it independently. Essentially, the teacher repeats the linking and blending of sounds three times. At each repetition, the teacher performs less of the process and gives greater responsibility to the child. At the end of the sequence, the child demonstrates the procedure by herself. More specifically:

1. The teacher models the blending procedure. He[3] models the sounds and the blends and uses finger-pointing procedures and intermittent verbal directions.

2. The children imitate the model while the teacher repeats both the verbal cues and the finger cues to assist them.

3. The teacher repeats the procedure, but this time does not model the sounds of the blends. He gives only the verbal cues and the finger cues to assist.

4. The procedure is repeated. This time, the teacher drops the verbal cues. He gives only finger cues (i.e., the prompts are faded).

5. The child performs the pointing, sounding, and blending steps independently.

A strong advantage of this blending procedure for the teacher is the precise information it provides in locating an error. If a child makes an error while performing the procedure, the teacher knows exactly where the error is, that is, which link in the process is incorrect. With this kind of precise information, the teacher can give the child a direct prompt. For example, if the child's inability to pronounce a word was caused by a substituted or omitted phoneme, the teacher would point to the letter and ask the child to say its sound. If she hesitated, he would prompt her with a silent mouthing cue. If necessary, he would model the sound. If the error was in a blend (e.g., the ca in cat), he would run his finger under the ca and ask the child to say the blend, he would cue the blend if the child hesitated, and if necessary he would model the blend. This kind of precise information helps the teacher adapt his behavior to the precise needs of the individual child.

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[3] Throughout this paper, but particularly in this section, we refer to the teacher as "he," to the child as "she." We do this merely to ensure clarity of exposition and intend no prejudice against female teachers and male children.

Context and Comprehension in Early Reading

We will turn in a moment to a consideration of the general processes of reading comprehension. But it is important first to consider the role of comprehension in early reading behavior. Learning to read is not a matter of learning to recognize words and then learning to comprehend. Rather, it is a matter of learning to recognize words in order to comprehend. We have already suggested that, in initial decoding, word recognition and some level of comprehension are closely interdependent. The decoding process involves testing a blended word against one's existing aural recognition vocabulary. A simple extension, one we will discuss more fully in a moment, is that the candidate word is tested for suitability to the immediate context. This testing in fact forms an integral part of the word attack process, although we have not shown it in our models yet. Many children--perhaps most-- appear to engage in this testing naturally, once they recognize that printed language is a schematic map of the spoken language they already know. The process can be assisted, however, by instruction that at a very early stage draws attention explicitly to context--for example, by requiring the child to choose the "best fitting" of two words for a given context, or by requiring her to indicate which specific segments of a text provide clues to a word's meaning. A variety of activities of this kind are included in our program from the earliest lessons. In addition, as the lessons progress and as increasing vocabulary and fluency are developed, a few simple comprehension activities are introduced, such as selecting the best fitting picture for a text of several lines, or following directions of several sentences' length. These activities are not intended to teach comprehension systematically. Rather, they help the reader to keep alert to the details of the text and to maintain a meaning-detection rather than a word-recognition orientation toward the process of reading.

Reading Comprehension: Mapping the Domain

We turn now to the possibilities for creating models of reading comprehension processes themselves. While we cannot yet offer models as detailed as those we have proposed for decoding, we can point with some optimism to work elsewhere that may provide deeper understanding of language comprehension in general and that may thus provide a basis for models of text comprehension. Such work includes artificial intelligence efforts on sentence processing (e.g., Winograd, 1972) and story comprehension (Charniak, 1972), simulation models of the understanding of verbal instructions (Hayes & Simon, 1974), and increasing empirical work on natural language and text processing.

What we can offer here is not a formal model, but a general map of the reading comprehension domain, a description that can direct attention to important psychological and instructional issues that should be addressed. Figure 5 is such a map. It represents the hypothesized flow of behavior for an effective reader reading a moderately difficult text. The individual might be a third grader reading a social studies text dealing with prehistoric animals or a college student reading this paper.

Although much less specific than the models shown earlier, Figure 5 retains the flow diagram format, because of the usefulness of this format in displaying the decision-making sequences that we assume to be characteristic of comprehension activity. Like the earlier analyses, Figure 5 contains two kinds of statements. direction statements (rectangular boxes) and queries (diamonds). Using the computer program analogy, the direction statements can be considered as subprograms that can be activated by the by the more general "reading" program. The queries are decision points at which the program assesses its own state and "decides" whether to continue or to enter a correction loop in which more information is sought. These decisions are not necessarily conscious. Rather, they represent

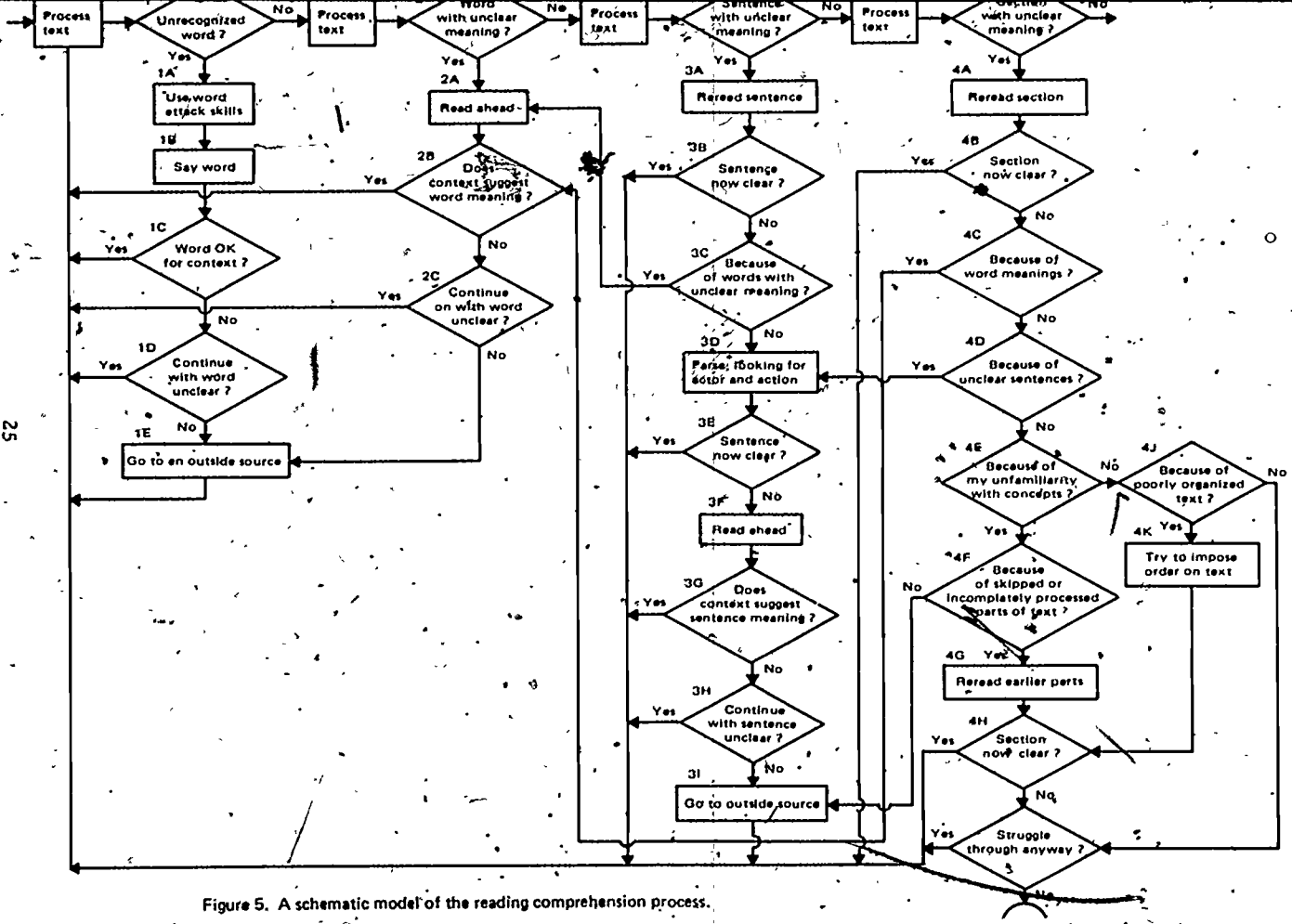

Figure 5. A schematic model of the reading comprehension process.

points at which the reader recognizes that deeper processing is needed for comprehension purposes. The top line of the figure describes the flow of processing and self-monitoring for a reader who encounters no difficulties at all in the course of reading. This is a rare occasion, of course. Most frequently, readers will encounter occasional difficulties in recognizing words or in interpreting meaning, these difficulties require readers to search for further information. These searches are described, in quite general terms, in the sequences shown below Queries 1 through 4.

An ongoing text processing activity is assumed (the Process Text boxes in the top line). This processing activity is interrupted by occasions on which the reader decides she has inadequate information and initiates a search for just enough information to satisfy her demands for an adequate level of comprehension. The first such interruption is for an unrecognized word (Query 1). It is important to note that a skilled reader will probably not interrupt reading for every unrecognized word, nor may she even attend to every separate word in the text (see Goodman, 1970). However, a certain "adequate" level of word recognition is required, and even skilled readers will occasionally encounter unrecognized words that are significant to the general meaning of the text and that necessitate the use of word attack skills to decode the word. The word attack strand as shown here is a very condensed statement of the decoding routines discussed in the first part of the paper. Boxes 1A and 1B are summaries of all of the material in Figures 1-3. Decision 1C represents a check for the pronounced word's semantic and syntactic suitability for the context. If an acceptable word has been found, the reader returns to the main text processing flow, otherwise, the reader must decide whether to continue reading with the word still unclear (1D) or to seek information from an outside source. The "outside source" for a decoding problem is likely to be another person, although finding the same word in another context sometimes solves the problem.

The second interruption indicated occurs when a word is sounded which has an unclear meaning and which appears important enough for comprehension to warrant further information search (Query 2). We assume that the most frequent first response under these conditions is to read ahead a little, searching for context that will suggest a meaning (2A). The success of this context search is tested at 2B. Success sends the reader back into the main processing strand, while failure gives her the same choices as before. to continue reading with the word unclear, or to utilize an outside source. Dictionaries, glossaries, and so on are available as outside sources, as well as other people, although other people may remain the preferred "least effort" source. We will see in a moment that the decision to continue with words unclarified may affect subsequent processing. Nevertheless, it is often a good choice in reading, depending upon the depth of comprehension required for a particular task and upon the degree of information redundancy.

At Query 3, processing is interrupted by awareness of a sentence or clause whose meaning is not completely clear. The reader's first action is probably to reread the sentence and to test for success in gaining meaning (3A and 3B). If simple rereading fails, a next reasonable test would be to determine whether individual words--perhaps those deliberately left unclear in early decisions--are the source of difficulty (3C), if so, then the word meaning strand is entered. If individual words are not the problem, attention must next be focused upon the syntactic and semantic structure of the sentence. The sentence must be parsed to reveal its basic structure (3D). This is a complex and still incompletely understood process, although some current models for sentence parsing (e.g., Winograd, 1972) may offer a basis for understanding this aspect of reading behavior. If parsing is successful in revealing meaning (3E), then the reader reenters the main processing strand, if parsing fails, then a number of decisions similar to those for individual words probably occur. The reader may decide to proceed with the sentence unclear (3H) or may turn to an outside source (3I).

We come finally, at Query 4, to a situation in which an entire section (for example a paragraph or a chapter) is judged unclear. As for sentences, the first likely act is rereading (4A). Next, unclear words (4C) or unclear sentences (4D) may be the source of difficulty. If so, the reader returns to the word meaning or sentence meaning strands. If neither of these seems to be the cause of difficulty, a set of further tests may occur. The reader may try to decide whether the present difficulty is due to her own unfamiliarity with the concepts discussed in the text (4E). If this seems a likely cause, perhaps it is due to incomplete processing of earlier parts of the text (4F), in which case rereading the earlier parts (4G) may help. If the difficulties do not appear to reside in the reader's unfamiliarity with the concepts (a "no" answer at 4E), the skilled reader may begin to wonder whether the text itself is so poorly written that it is the cause of the problem (4J). She may then try to impose order on the text (4K). If all of these tests and actions fail to produce clarification (a "no" answer at 4J and 4H), a fundamental decision must finally be made--whether to struggle ahead anyway. We suspect that many children in school do struggle through, with very little comprehension, simply because they have been told to read something. People reading independently will rarely do this, nor would we reasonably expect them to.

The model we have presented here, as we stated at the outset, represents only a general mapping of reading processes. It suggests in broad terms the probable major components of the reading process and how these components might interact, it does not attempt to describe the processes in detail. Some simplifying assumptions have been made. For example, we assume a highly motivated reader. We also assume the availability of an outside source for help--an assumption that is not always fulfilled in school reading situations. Further, we have depicted deliberate "decisions" for situations in which choices are probably made much less explicitly. Nevertheless, even in this simplified outline state, we believe

the model as presented helps to make evident certain important features of reading. Perhaps the most important feature is the indeterminacy of the process, its trial and error character. Reading is not an algorithmic process in which straightforward application of a set of rules or procedures will invariably yield comprehension of a text. Rather, it is a kind of interaction with a text, an interaction in which information is sought at various levels of specificity and in which a gradual reduction in "unknowns" is sought as more and more of the text is processed.

One general suggestion for reading instruction that emerges from this characterization is that readers be explicitly taught some of the self-monitoring strategies implied by the model. Even if we are still unable to specify the details for some of the processes outlined, it seems likely that alerting readers to the kinds of difficulty that may be encountered and to some broad strategies for dealing with the difficulties may be very powerful. Recent work in mathematical problem solving suggests that self-consciousness about goals and overt planning can increase success (e.g., Greeno, 1973; Resnick & Glaser, in press). Some of the same principles are probably applicable to reading. What the present model outlines are some of the strategies for conducting the interaction, and these strategies are shown to be heuristic--that is, to depend on the reader's judgment along the way concerning how well she is gathering and interpreting the necessary information.

The model also suggests that reading is a very context-bound activity, that is, that the characteristics of the text will have a very great effect upon what constitutes an effective reading strategy. Thus, there is no single way to read well. Even the most skilled of readers will sometimes encounter texts that are not processed without considerable search activity. Further, success in reading is partly knowledge-bound. Much depends upon the knowledge the reader brings to the text. Unfamiliarity with the subject-matter concepts is often a cause of difficulty in comprehension, unless the

text is explicitly designed to introduce the reader to a new substantive area. The instructional implication is that reading comprehension may best be taught in the context of a variety of subject matter rather than as a separate discipline, in order to allow the acquisition of a broad range of knowledge as the basis for effective reading.

Next Steps

We have offered a general proposal about the relationship between psychological theory--especially information-processing descriptions of complex tasks--and the design of instruction. We have described a process in which rational analyses of reading were developed in response to questions raised by problems of instruction, and we have shown some of the ways in which these models have guided the design of a reading program. Our models must be regarded as hypotheses for the moment, since we have not offered firm evidence of their validity as descriptions of how people read. But we have suggested a strategy for testing them.

The strategy proposed is an iterative one: model building and refinement, based on instructional efforts. We believe that attention to modeling the reading process will become increasingly important as instructional efforts in reading shift focus from decoding to the syntactic and semantic processes involved in comprehension. In this paper we have attempted to show that even the relatively simple skills of word attack involve heuristics of judgment and self-monitoring. Such is even more strongly the case for comprehension skills, and for this reason careful theory generation and testing is especially required. Our current capacity to describe what is to be taught in the way of comprehension abilities is extremely limited. The best we now have are taxonomies, lists of classes of stimuli and classes of responses, sometimes ordered according to relative difficulty or complexity. Until we "look inside" to find out what processes mediate the behaviors we call comprehension, we can expect little progress beyond the activities

that now fill children's intermediate and middle school days but that seem to fail so many children so badly.

At the risk of prediction made too soon, we would like to suggest that instruction based on models of language comprehension, such as are now beginning to emerge from both experimental cognitive work and related computer modeling, is likely to differ significantly from what we now know in reading comprehension. First, we are likely to focus heavily on helping children build extensive bodies of knowledge that will help them interpret the new materials they encounter in written texts, this will mean less reliance on collections of brief, unrelated reading selections in favor of extended reading and related experiences in a few areas of interest. Second, we are likely to teach children general strategies of reasoning and thinking, since it appears unlikely that comprehension of written material will involve totally different processes than comprehension of oral language. Third, we will probably teach children more explicit mediational strategies for organizing and remembering what they read (strategies such as visual imaging, self-questioning, regrouping of information, etc.). Fourth, we are likely to try to help children become aware of their language processes and call deliberately on their most effective strategies. We will seek, in other words, to establish what might be called a system of "meta-comprehension" by which children can monitor and organize their own comprehension processes.

Such are our predictions. Our prescription for the next step is to begin testing these predictions, intensifying for complex comprehension skills the iterative process of model building, instructional design, and experimental testing that is now well begun for initial reading.

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