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ABSTRACT

This paper is focused on a relatively new emphasis in education research: the nature of academic work contained in the curriculum of elementary and secondary schools, how that work is organized and accomplished in classrooms, and what modifications in academic work are likely to increase student achievement. The paper is divided into two major sections. The first section is devoted to an analysis of the intellectual demands inherent in different forms of academic work. Of special importance in this section is the recent work on cognitive processes which underlie school tasks. The second section is directed to studies of how academic work is carried on in classroom environments. Particular attention in this section is given to the ways in which social and evaluative conditions in classrooms affect students' reactions to work. Each section contains an analysis of implications for improving the quality of academic work in classrooms and thus increasing student achievement. Also present is an extensive bibliography (21 pages). (JM)

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This paper is focused on the nature of academic work contained in the curriculum of elementary and secondary schools, how that work is organized and accomplished in classrooms, and what modifications in academic work are likely to increase student achievement. This concern for academic work represents a relatively new emphasis in educational research. Traditionally, investigators have concentrated on general characteristics of teachers or instructional programs, such as the amount of praise, the frequency and types of questions, time spent lecturing, and ways of providing feedback and reinforcement (Anderson, et al., 1969; Rosenshine, 1971). Recently, attention has expanded to include student perceptions and behavior in classrooms as well as the cognitive operations involved in learning the school curriculum (Anderson, Spiro, & Montague, 1977; Doyle, 1977; Levin & Wang, 1982; Rosenshine, 1979; Weinstein, 1982). With this expansion has come an awareness of the need to understand more fully the intrinsic character of academic work and how that work is experienced by students in classrooms.

The paper is divided into two major sections. The first section is devoted to an analysis of the intellectual demands inherent in different forms of academic work. Of special importance to this section is the recent work on cognitive processes which underlie school tasks. The second section is directed to studies of how academic work is carried out in classroom environments. Particular attention in this section is given to the ways in which the social and the evaluative conditions in classrooms affect students' reactions to work. Each section contains an analysis of implications for improving the quality of academic work in classrooms and thus increasing student achievement.

The Intrinsic Character of Academic Work

For several years sociologists and historians of education have called attention to relationships between schooling and the adult world of work (see Barr & Dreeben, 1977; Dreeben, 1968; Hurn, 1978; Tyack, 1974; Westbury, 1979; Willis, 1977). These analyses have focused on the extent to which the regularities of schooling, by placing emphasis on punctuality, patience, production schedules, and obedience, provide training in a work ethic uniquely suited to the requirements of an industrialized society. In other words, school "work" often appears to instill dispositions appropriate for entering the labor market. But this relationship between schooling and work is generally thought to be an incidental or "hidden" aspect of school experience, an effect that occurs indirectly from the way schools are organized and managed. The focus of the present paper is on the direct effects of the curriculum, on what students learn by studying language or mathematics or any of the other contents of the school program. Nevertheless, the concept of "work" provides a useful metaphor for approaching an analysis of what students do in school.

The Curriculum and Academic Tasks

In very broad terms the curriculum of the early elementary grades reflects an emphasis on fundamental operations in reading and mathematics, the so-called "basic skills." In addition, pupils are exposed to information about social studies, music, nutrition, art, and physical fitness. The emphasis on basic skills is apparent in the way time is allocated in these grades. In the Beginning Teacher Evaluation Study, for example, it was found that approximately 55% of the day in second and fifth grade classes was spent in language arts and math, and these figures are generally consistent with those obtained in earlier studies (see Borg, 1980; Rosenshine, 1980).

As students progress through the grades, the emphasis gradually shifts from basic skills to the content and methods of inquiry embodied in the academic disciplines. Older students are expected to learn algebra, history, biology, and literature, rather than simply practice reading and computational skills. Also in the middle school or junior high school years, students begin to develop the capacity for formal operational thought, that is, the ability to think abstractly and use general strategies to analyze and solve problems (see Johnson, 1980). Clearly the expectations for school work become more technical and more demanding over the years.

This brief topical description of the curriculum provides a useful overview of students' work at different grade levels, but it gives little sense of the inherent demands of that work. For this latter purpose it is necessary to view the curriculum as a collection of academic tasks (see Doyle, 1979b, 1980b). The term "task" focuses attention on three aspects of students' work: (1) the products students are to formulate, such as an original essay or answers to a set of test questions; (2) the operations which are to be used to generate the product, such as memorizing a list of words or classifying examples of a concept; and (3) the "givens" or resources available to students while they are generating a product, such as a model of a finished essay supplied by the teacher or a fellow student. Academic tasks, in other words, are defined by the answers students are required to produce and the routes which can be used to obtain these answers.

Tasks influence learners by directing attention to particular aspects of content and by specifying ways of processing information. These effects are clearly apparent in the contrast between semantic and nonsemantic processing, i.e., the processing of information for meaning versus the processing of information for surface features (see Bransford, Nitsch, & Franks, 1977; Postman & Kruesi, 1977). If subjects in an experiment are required to count the number of X's embedded in a photograph, they are not likely to remember much about the scenes or faces depicted. If they are asked to identify words that rhyme in a passage, they will remember less about the main ideas than if they are instructed to summarize the gist of the passage. Similar effects have been reported in other areas. Several investigators have found that pupils adjust strategies for selecting and processing information depending on whether they expect a test to measure recall, recognition, or inferences (see McConkie, 1977, for a review). There is even evidence that eye movements and the width of gazes are affected by the nature of different reading tasks (see Gibson & Levin, 1975, pp. 360-372). In sum, "the nature of exploratory behavior with respect to any stimulus configuration is modulated by the task in which the subject is involved at the time of encounter." (Nunnally & Lemond, 1973).

A good example of how tasks affect information processing is Barr's (1975) study of errors made by first-grade pupils when trying to pronounce unfamiliar words during oral reading. Barr found that pupils taught by a sight-word method (which focuses on whole words as the basic unit of reading) substituted words from the sample of reading words contained in the instructional materials, made few non-word responses, and showed little letter-sound correspondence in attempts to pronounce the unfamiliar words. On the other hand, pupils taught by a phonics method (which focuses on sounds as the basic unit of reading) made more non-word or partial-word responses, showed high letter-sound correspondence in making substitutions, and substituted words not contained in the instructional materials. In these results, it is clear that pupils used problem-solving strategies that were consistent with the way in which each method defined the reading task.

The resources available to students also affect the nature of academic tasks. Writing an original descriptive paragraph can be a challenging task for students in upper elementary grades or junior high school. If, however, the paragraph can be produced by combining short, simple sentences supplied by the teacher into more complex sentences, then the demands of the task on students' writing abilities are reduced substantially. In other words, "writing" in the two situations (original essay vs. sentence combining exercise) refers to fundamentally different tasks. For this reason, content labels, such as "grammar," "multiplication," or "current events," are not very useful for describing the academic tasks students are required to accomplish.

This preliminary section can be summarized in two basic propositions:

1. Students' academic work in school is defined by the academic tasks that are embedded in the content they encounter on a daily basis. Tasks regulate the selection of information and the choice of strategies for processing that information. Thus, "changing a subject's task changes the kind of event the subject experiences" (Jenkins, 1977, p. 425).
2. Students will learn what a task leads them to do, i.e., they will acquire information and operations which are necessary to accomplish the tasks they encounter (see Frase, 1972, 1975). In other words, accomplishing a task has two consequences. First, a person will acquire information--facts, concepts, principles, solutions--involved in the particular task that is accomplished. Second, a person will practice operations--memorizing, classifying, inferring, analyzing--used to obtain or produce the information demanded by the task.

Types of Academic Tasks

Considerable effort has been expended in recent years to define the cognitive components of "real life" school tasks (see Anderson, Spiro, & Montague, 1977; Calfee, 1981; Glaser, 1978; Klahr, 1976). This work is part of a broader movement in psychology toward the analysis of cognitive processes which underlie various aspects of human aptitude and performance (see Curtis & Glaser, 1981; Greeno, 1980; Resnick, 1976). In this section, some of the general concepts and findings emerging from this research will be reviewed and illustrations from the fields of reading, mathematics, science, writing, and literature will be given. The central purpose of this selective review is to define more fully the nature of school work, that is, the character and range of learnings that are explicitly or implicitly contained in the curriculum of elementary and secondary schooling.

General categories of academic tasks. The academic tasks embedded in the curriculum can be differentiated in terms of general categories of cognitive operations which are involved in task accomplishment (see Greeno, 1976; Merrill & Boutwell, 1973). For illustrative purposes, four of these general types will be identified here (see Doyle, 1980b):

1. memory tasks in which students are expected to recognize or reproduce information previously encountered (e.g., memorize a list of spelling words or lines from a poem);
2. procedural or routine tasks in which students are expected to apply a standardized and predictable formula

or algorithm to generate answers (e.g., solve a set of subtraction problems);

3. <u>comprehension or understanding tasks</u> in which students are expected to (a) recognize transformed or paraphrased versions of information previous encountered, (b) apply procedures to new problems or decide from among several procedures those which are applicable to a particular problem (e.g., solve "word problems" in mathematics), or (c) draw inferences from previously encountered information or procedures (e.g., make predictions about a chemical reaction or devise an alternative formula for squaring a number);

4. <u>opinion tasks</u> in which students are expected to state a preference for something (e.g., select a favorite short story).

These general catgories can be specified more fully by contrasting individual task types. A useful place to begin is with a basic distinction between tasks which can be accomplished by verbatim reproduction of content previously encountered (memory tasks) and tasks which can be accomplished by understanding the gist of a text (comprehension tasks).

<u>Memory versus comprehension</u>. The contrast between memory and comprehension tasks is based on a distinction between surface structure (that is, the exact words printed on a page) and conceptual structure (that is, the underlying network of propositions that define meaning of a text). Memory tasks direct attention to the surface of a text and to the reproduction of

words; comprehension tasks direct attention to the conceptual structure of the text and to the meaning which the words and sentences convey. In other words, "verbatim information consists of propositions about the physical sentences, whereas gist information consists of propositions about the referents of the sentences" (J. R. Anderson & Paulson, 1977).

R. C. Anderson (1972) has approached the distinction between memory and comprehension from the perspective of test items. Verbatim items (that is, items which contain the same examples or the same language used in instruction) measure recall but not necessarily comprehension. Paraphrase items (that is, items which contain new examples or a transformed version of the language used in instruction) allow a more confident inference that students understood the information. To this list can be added inference items, that is, items which ask for information not explicitly stated in the text but available through inferences from what is stated or items which require use of the information in the text to formulate new propositions or relationships (see Gagne & White, 1978; Trabasso, 1981).

One of the essential differences betweeen memory and comprehension tasks is that they require different strategies for processing information (see Brown, 1975; Craik, 1977). In comprehension tasks, the ideas represented in the surface structure of a text are decontextualized and organized into a high-level propositional network or schema (see Bransford & Franks, 1976; Kintsch, 1975; Rumelhart, 1981). (The concept of "schema" is discussed more fully in a subsequent section.) Such a network contains little of the original surface features of the text from which the abstract propositions were formed. Schema are generative, however (see Shaw & Wilson, 1976; Wittrock, 1974). That is, schema can be used with great flexibility to interpret unencountered instances with ease or to generate inferences about the application of concepts and propositions to new situations. In other words, it is possible to answer paraphrase and inference items using a schema which serves as a generator set for such answers.

In comprehension tasks, remembering is an incidental product of comprehension (Brown, 1975). In Norman's words, "If I fail to understand, I will also fail to remember" (1975, p. 531). Memory for information acquired by comprehension is more durable, but there is a leveling and sharpening of the original text so that reproduction of the surface structure of the text becomes difficult. In other words, semantic integration takes place so that a person remembers the gist of the text rather than the precise words or examples used originally (see Bransford & Franks, 1971; Paris, 1975).

To accomplish comprehension tasks, then, a student must build a high-level semantic structure or schema that can be instantiated in several ways as particular circumstances demand. The construction of such schemata in academic areas is likely to be difficult and to require extended experience with the content (see

Bransford & Franks, 1976; Nelson, 1977). Before such a schema is constructed, involuntary remembering is not likely to operate efficiently.

Memory tasks come into existence under three conditions. First, a task may require an exact replica or a very close approximation of the original form of the information, such as dates, quantities, names, terms, or other facts. Many laboratory studies of memory use tasks of this character. In addition, portions of many school subjects (e.g., multiplication tables, names of elements in the periodic chart, etc.) require memorization. Second, a task may be heavily dependent on recall if making an inference or applying a formula requires that students remember a large amount of factual information. Finally, a task may require that a student know information which he or she cannot understand (that is, assimulate to a schema). In such a situation, the student is likely to accomplish the task by memorizing the text. For example, the sentence "Groundwater returns to the ocean during the hydrologic cycle" might well be learned by memorizing rather than understanding. Rote learning of inherently meaningful material is likely to happen when a student does not have sufficient background or time to construct a semantic representation of the information.

In any one of these circumstances, deliberate memorizing is required so that a person can at least reproduce the original information. Deliberate memorizing requires at least two processes (see Brown, 1975). First, a person must resist semantic integration, that is, separate the new information from what is already known, in order to preserve in memory the surface features of the text that is to be reproduced (see Dooling & Christiaansen, 1977; Spiro, 1977). Second, a person must use some type of mnemonic strategy to generate rich associations for the information to make it more durable in memory (see Craik, 1977; Levin, Shriberg, Miller, McCormick, & Levin, 1980; Rohwer, 1973). In some cases, information might be linked in memory to its location in a passage or its place on a page (see Just & Carpenter, 1976; Rothkopf, 1971; Schulman, 1973; Zechmeister, McKillip, Pasko, & Bespalec, 1975). Recall of information that is learned in this manner is often dependent on the similarity between the conditions of testing and the conditions of studying.

The distinction between memory and comprehension tasks must be viewed as a matter of degree. Some tasks are weighted toward verbatim reproduction of the language used in instruction. Other tasks are weighted in the direction of paraphrases or inferences. In addition, comprehension items under some circumstances may be answerable by recall, thereby allowing memory to be a route to accomplishing what is nominally a comprehension task. If, for instance, an item that requires a person to give an example of a concept can be answered by reproducing an example used in instruction, then the item can be answered by memory. In such a case it is not necessarily appropriate to infer comprehension from a correct answer.

<u>Procedural versus comprehension tasks</u>. A distinction between procedural tasks and comprehension tasks is especially clear in

the field of mathematics. There is a difference between (a) knowing an algorithm, such as the computational steps for adding a column of numbers or multiplying two-digit numbers, and (b) knowing why the procedure works and when it should be used (see Davis & McKnight, 1976; Glaser, 1979; Greeno, 1978). Procedural tasks, then, are tasks which are accomplished by using a standard routine that produces answers. There is typically little unpredictability in such cases because the routines or algorithms are very reliable, that is, they consistently generate correct answers if no computational errors are made. Comprehension tasks, with respect to procedures, are tasks which are accomplished by knowing why a procedure works or when to use it.

Although procedural tasks are especially evident in mathematics, they also operate in other academic areas in which rules are used to produce answers. Grammar, for example, consists largely of procedures for classifying components of sentences. Similarly, reading at the level of decoding letter-sound correspondences is a rule-like process for naming words correctly.

In a very broad sense, a large part of thinking is algorithmic (see Davis & McKnight, 1976). Nevertheless, there are levels of specificity that must be considered in distinguishing between procedural and understanding tasks. A procedural task is one which can be accomplished without understanding by simply knowing how to follow a series of computational steps. Understanding tasks, on the other hand, require knowledge about why the computational steps work. Procedural tasks are often limited to content for which specific algorithms can be constructed. In some areas, such as composition, specific formulas for generating paragraphs may not exist. Yet even in this case procedural tasks can be created. Sentence-combining, in which simple sentences are combined into more complex sentences (see O'Hare, 1973), has many of the properties of algorithms in mathematics or grammar.

To accomplish a comprehension task related to procedures, a student must be able to construct a cognitive representation of the ideas embedded in the algorithm or conceptualize a problem in terms of the procedures which are likely to apply (see Gagne & White, 1978; Greeno, 1978). As was true of comprehension of information, constructing a high-level schema necessary for understanding a procedure and the circumstances under which it applies is a more lengthy and difficult process than learning to follow a largely invariant sequence of steps to produce an answer.

The relationship among different tasks. A comparison of memory and comprehension tasks suggests that preparation suitable for one type may not necessarily be suitable for the other (see Bransford & Franks, 1976; Kintsch, 1975). Accomplishing a comprehension task can, because of the effects of semantic integration, interfere with the ability to reproduce specific facts or the surface features of the original text. On the other hand, accomplishing a memory task can produce knowledge in a form that is not easily applied to recognizing new instances or making inferences to new situations. Thus, reading for comprehension may be inappropriate for a recall task. It is probably for this reason that students typically adjust study strategies to fit the nature of the test they expect to take (see McConkie, 1977).

A parallel argument can be made for procedural and comprehension tasks. Learning to use an algorithm does not necessarily enable one to understand why the algorithm works or when to use it. Similarly, learning to understand why an algorithm works or when it should be used does not necessarily lead to computational proficiency (see Resnick & Ford, 1981). Greeno (1976) has pointed out, for example, that numerical representations of fractions (e.g., 1/2 or 1/6) are efficient for producing answers to textbook problems but do not necessarily depict the nature of fractions or facilitate transfer to new concepts related to fractions. For these latter purposes, spatial representations (e.g., squares or circles) are more appropriate although they are cumbersome for computation.

It is often argued that extensive drill and practice with computational procedures is a prerequisite for acquiring an understanding of the material. The present analysis suggests, however, that accomplishing one task does not automatically lead to the outcomes of the other. Indeed memory, procedural, and comprehension processing may interfere with each other in accomplishing a given task.

Some Emerging Themes

Analyses in such curriculum areas as reading, mathematics, science, writing, and literature, have produced some common insights concerning the character of academic work and students' performance on tasks. In this section some of this research is summarized. As before, the review is not intended to be comprehensive. Rather, some of the main lines of inquiry delineated and the major promising directions are indicated. Given the preliminary nature of much of the research in this area, such selectivity is justified.

Comprehension of texts. Work in modern cognitive psychology has had a major impact on knowledge about the processes involved in comprehending texts. A central premise of cognitive science is that comprehension is a constructive process (see Bransford & Franks, 1976; Kintsch & van Dijk, 1978; Schank & Abelson, 1977). According to this premise, meaning does not result from a passive reception of information from the environment. Rather, understanding involves the construction of a cognitive representation of events or concepts and their relationships in a specific context.

The process of constructing a cognitive representation is interactive and sequential, involving information from the environment and from semantic memory (Rumelhart, 1981). In comprehending prose, for example, a reader gradually builds a model of the semantic structure of the passage. Information from the environment makes contact with information from semantic memory to suggest a likely interpretation. This interpretation establishes expectations about what subsequent events will likely be. These expectations, in turn, guide procesing of new information in working memory, that is, they restrict the options for interpreting incoming data. Thus, the interpretation of the word "saw" depends upon whether the passage is about looking or cutting a board. Finally, new information is used to update the initial interpretation as the reader progresses through a passage.

A person's knowledge of the world is organized into associational networks or schemata (see Rumelhart, 1981). A schema is a relatively abstract representation of objects, episodes, actions, or situations which contains slots or variables into which specific instances can be fit in a particular context.

This organizational view of knowledge emphasizes the multiple associations of information in long-term memory. The word "apple," for instance, is embedded in a network of associations referring to shape, color, texture, use, and relation to other foods. In contrast, the word "brick" elicits quite different associatons. [Schemata also exist at the level of stories (Stein, 1979), episodes (Bower, Black, & Turner, 1979), and social situations (Schank & Abelson, 1977).] As words are encountered in a text they activate associations which establish expectations and enable the reader to construct a propositional representation of the text in memory. The process of comprehension, then, "can be considered to consist of selecting schemata and variable bindings that will 'account for' the material to be comprehended, and then verifying that those schemata do indeed account for it. We say that a schema 'accounts for' a situation whenever that situation can be interpreted as an instance of the concept the schema represents" (Rumelhart & Ortony, 1977, p. 111).

Schemata play an especially important role in accounting for ambiguities in passages or situations and in making inferences (see Schank & Abelson, 1977; Trabasso, 1981). Passages or episodes are seldom fully specified. In building a cognitive representation, therefore, a person must make inferences to complete the picture of associations and causality among concepts and events. Thus, in reading the sentence "George entered a restaurant" a reader can use a restaurant schema to fill in what is likely to happen. Similarly, the sentences:

Michael took the key from Steven.

Steven called the police.

permit the inference that Michael probably stole the key. This process of making inferences appears to play a central role in what is known as "semantic integration" of information from stories (see Brown, 1976; Paris, 1975).

In addition to knowledge structures in long-term memory, readers use structures embedded in texts to guide comprehension. Meyer (1975; see also Meyer, Brandt, & Bluth, 1980) found, for example, that concepts high in the organizational structure or conceptual hierarchy of a passage are recalled better than concepts lower in the hierarchy. These findings suggest that readers use the semantic organization of a text to select and process information. Similar results have been reported for story structures (Stein, 1979). In other words, comprehension is not solely a matter of imposing personal knowledge on the world. Passages and episodes carry instructions which readers use to construct meaning.

From this perspective, then, the task of learning to read means learning to construct semantic representations of passages. Of course, beginning readers must also learn letter-sound correspondences or "code breaking" processes (see Beck, 1977; LaBerge & Samuels, 1976). That is, a reader must be able to recognize that printed symbols represent sounds and then become proficient in interpreting these symbols rapidly in continuous text. These decoding operations are not completely separate from comprehension processes for two reasons. First, if a pupil does not know the code of letter-sound correspondences, then access to the content of a passage is obviously impossible. Second, comprehension of a passage often facilitates decoding by creating expectations about what items of information are likely to be presented next.

The central role of prior knowledge. Work on general comprehension skills in reading has been extended recently by research within particular subject matter domains, such as science and mathematics. Much of this work is focused on differences between the performance of experts and novices as well as the effects of the understanding which novices bring to content. The purpose of this work is to identify the competencies and knowledge structures required for gaining mastery in these domains. Given both the topical focus as well as an interest in direct application to real life instructional problems, this work is an important resource for understanding and improving academic work in schools (see Glaser, 1978).

One of the major findings of research in this area is that domain-specific knowledge plays a central role in problem solving and learning within a content area. Domain-specific knowledge consists not only of a well-formed semantic network of valid information in an academic discipline but also strategies for using this information to represent (comprehend) problems, search for and select algorithms, utilize resources from the task environment, and evaluate the adequacy of answers (see Resnick & Ford, 1981, pp. 196-237, for a discussion of this point with reference to mathematics).

The operation of these factors is evident in studies comparing the performance of experts and novices in solving physics problems. In a series of studies Larkin (1981) found several differences between experts and novices in speed, number of errors, and the immediacy of access to a variety of solution strategies. Her results also hinted at a qualitative difference in the way problems were initially analyzed and represented by the two groups. Chi, Glaser, and Rees (1981) conducted studies designed to explicate more fully how experts represent problems. They found that the difficulties novices encountered in solving physics problems stemmed primarily from deficiencies in their knowledge of physics rather than in their information-processing strategies or capacities. Experts, because they understood physics better, were able to represent problems in terms of underlying principles. Novices, on the other hand, focused on the literal details of the problems and their knowledge seemed to be organized around isolated events and concepts rather than underlying principles. As a result, they were unable to make key inferences necessary for arriving at a solution or know when to use what they did know.

Similar results have been reported for expert-novice differences in cognition during writing (see Flower & Hayes, 1981; Perl, 1979; Matsuhashi, 1981). Both experts and novices spend a good deal of time thinking about individual sentences as they actually produce text. But experienced writers combine sentence planning with planning addressed to the audience, the genre, and the semantic structure or schema of the entire essay. Novices, on the other hand, were concerned about what to write next and limited their planning to thinking about the topic or assignment and about the last sentence they had written. Thus they failed to develop an adequate goal structure for the total work to guide their sentence planning.

Finally, Spiro (1979) has conceptualized the development of a "comprehension style" in terms which parallel those used in expert-novice studies. He argues that less able readers tend to focus excessively on decoding letter-sound correspondences to the detriment of comprehension, and that this orientation results in part from a lack of adequate knowledge structures for the text being read, lack of proficiency in decoding, and misconceptions about the reading process.

Studies focusing on the understanding that novices bring to science have also pointed to the key role of prior knowledge in academic work. DiSessa (1982), for example, reported that the naive physics knowledge of a group of elementary pupils was surprisingly systematic and "Aristotelian," that is, they believed that objects should move in the direction they were last pushed. DiSessa also found that a protocol of an undergraduate student dealing with the same task showed congruence with the strategies of the elementary students, suggesting a strong persistence of naive knowledge. Eaton, Anderson, and Smith (1982) studied the way preconceptions of how light enables us to see objects influenced science learning among fifth-graders. They conducted a case study of the way a textbook unit on light was taught in two fifth-grade classes. In general the students had a preconception that light brightens objects so we can see them. The accurate conception is that we see objects because light is reflected off them to our eyes. The researchers found that students' preconception about light and vision persevered during teaching, in part because neither the teacher or the textbook specifically addressed this preconception. As a result, many of the students never really understood the content in the unit.

These studies suggest strongly that performance on academic work, especially in technical subject matter areas, is dependent upon domain-specific knowledge rather than general problem-sovling strategies alone. Thus attention needs to focus on the schemata that students bring to their academic work. In the absence of appropriate knowledge structures students are likely to: (a) use memorizing strategies to accomplish tasks, or (b) exhibit a discontinuity between what they are able to state about a field and what they actually do in solving problems (see Resnick & Ford, 1981). In all cases, they are not likely to understand what they are being taught.

Algorithms and systematic "errors." Research in academic areas has also focused on the acquisition of specific computational skills or algorithms, such as addition and multiplication routines in mathematics or decoding skills in reading (see Beck & McCaslin, 1978; Resnick & Ford, 1981). Traditionally, work on the acquisition of algorithms has focused on identifying and describing specific procedures in operational terms and on examining how various conditions of drill and practice foster mastery of these routines. Recently two important directions for inquiry have been taken: (1) research on students' invention of computational routines, and (2) studies of the systematic nature of students' errors. A brief review of these areas will demonstrate their contribution to an understanding of the nature of academic work and how that work can be improved.

Research on the acquistion of arithmetic routines has recently shown that students acquire knowledge about solution strategies "naturally" from their experience of trying to solve various types of problems and that they use this knowledge to invent procedures for solving routine problems. A study by Groen and Resnick (1977) provides a clear example of this invention. Preschool children were taught an addition algorithm in which problems of the form $\underline{m} + \underline{n} = x$ were to be solved by counting out $\underline{m}$ blocks, counting out $\underline{n}$ blocks and then counting the combined set.

This procedure represented the structure of mathematics well and was easy to teach and to learn. However, the procedure was often cumbersome for generating answers. With practice, but without further instruction, the children transformed the procedure into a more efficient routine in which they began with the larger number and then counted out the smaller number. This "invented" routine was more efficient for solving addition problems but was very difficult to explain directly to the children.

In Groen and Resnick's study, invention led to a deeper understanding of content and a more efficient procedure for solving problems. But interview studies with children have demonstrated that invention can have deleterious effects. Peck, Jencks, & Chatterley (1980) found, for example, that average-ability elementary students could successfully solve workbook problems with factions but could not represent factions accurately on diagrams. One common mistake was to assume that the denominator was the number of segments a circle was divided into, even though the segments were unequal. Thus, a circle divided in one half and two fourths was interpreted as being divided into thirds. These and other answers about the diagrams indicated some fundamental misconceptions about fractions, misconceptions which prevented the pupils from recognizing that an answer was clearly wrong. Even more dramatic evidence was uncovered by Erlwanger (1975) in his interviews of students considered successful by their teachers. When these students were probed carefully about their understanding of mathematics, they showed basic misconceptions. One student in particular, who spent four years working in an individualized mathematics program, invented a large number of rules which he used to produce answers which matched the answer key. From the perspective of mathematics, however, these rules were fundamentally erroneous.

In addition to acquiring misconceptions of content, students have also been found to invent "buggy" algorithms, that is, solution strategies which are systematic but wrong (see Brown & VanLehen, 1979, and Davis & McKnight, 1979 in mathematics; Spiro, 1979, argues that "bugs" operate in reading comprehension). One example of a bug in multi-digit subtraction occurs when a student is faced with subtracting a column in which the top digit is smaller than the bottom digit: e.g.,

$$\begin{array}{r} 460 \\ \underline{79} \end{array}$$

Instead of borrowing, the student subtracts the top digit, which is smaller, from the bottom digit, which is larger, to get an answer of 419 rather than the correct answer of 381. Bugs probably derive from a least two sources: (1) different algorithms which have a similar appearance (e.g., rules for forming the demoninator in adding and in multipying factions) are erroneously blended or one is substitute for the other; and (2) an algorithm is "repaired" by a student when he or she encounters an impasse while solving a particular problem. What is important in both cases is that bugs are systematic (that is, they have all the properties of a correct procedure) and therefore are not perceived as erroneous by students who use them. Thus, simply telling a student that an answer is wrong does not help correct the bug which produced it. Rather, the incorrect answer must be analyzed to discover the rule which is being followed. Unfortunately buggy algorithms are often practiced for a relatively extended period before they are recognized and thus correcting them is difficult.

Task complexity. Studies of the cognitive processes underlying academic work have revealed the enormously complex character of the operations and decisions that academic competence entails, a complexity that is often overlooked when the goals of schools are discussed. This complexity is evident in the areas of reading and domain-specific problem solving that have already been discussed. Two additional examples of content typically contained in the secondary curriculum will show the generality of this point.

The first example is from the field of literature. Although the cognitive processes involved in responses to literature have not been studied extensively, some recent analyses have indicated the complex operations required to understand literary works, especially fiction and poetry. Ortony (1980), for example, has begun to delineate the processes involved in comprehending and producing metaphors. The use of a figurative rather than a literal referent in a text requires a reader to shift schema in order to construct meaning. In addition, figurative referents allow for more than one interpretation, a condition which complicates understanding even further. It is reasonable to expect, therefore, that reading metaphors is a difficult task to master.

In an intriguing analysis of literary competence (which is presumably a central purpose of secondary English), Culler (1980) has provided insights into the conventions and processes a reader must know implicitly to understand poetry. Such conventions include the following:

1. "the rule of significance: read the poem as expressing a significant attitude to some problem concerning man and/or his relation to the universe" (p. 103).
2. "The conventions of metaphorical coherence--that one should attempt through semantic transformations to produce coherence on the levels of both tenor and vehicle..." (p. 103).
3. "the contention of thematic unity" (p. 103) which forces a reader to integrate into the total poem meanings associated with individual images.

In addition to conventions such as these, a reader must know various poetic traditions which assign universal meanings to certain images, such as water for life or sunset for death. Culler argues that:

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

From these perspectives, academic work in literature consists of a complex strategies and domain-specific knowledge for constructing meaning from literary languages.

The complexity of academic work is also apparent in recent analyses of the composing process (see collections by Cooper & Odell, 1978; Frederiksen & Dominic, 1981; Gregg & Steinberg, 1980; Nystrand, 1982). Research has focused on the phases of writing (e.g., prewriting, composing, revising, and editing), various types of written products, the development of writing ability, and differences between proficient and unskilled writers. Text production is seen as a recursive process which combines knowledge about a subject, an audience, vocabulary, and syntax with strategies for planning sentences, paragraphs, and texts for particular purposes. Frederiksen and Dominic (1981) summarize the elements of composing as follows:

> As a cognitive activity writing involves the use of specific kinds of knowledge that a writer has and is able to discover in constructing meanings and expressing them in writing. Underlying and enabling this use of knowledge are a variety of cognitive processes, including: discovering or generating an intended propositional meaning; selecting aspects of an intended meaning to be expressed; choosing language forms that encode this meaning explicitly and, simultaneously, guide the writer/reader through different levels of comprehension; reviewing what has been written, and often revising to change and improve meaning and its expression (p. 2).

From this description it is clear that writing "is among the most complex of human mental activities" (Flower & Hayes, 1981, p. 39). In turn, it is not surprising that many students find writing tasks in school difficult to accomplish.

The influence of age and ability. The subjective complexity of any task obviously depends upon the age and ability of the learner. Proficient readers, for example, use decoding processes automatically (LaBerge & Samuels, 1976), that is, they are able to recognize printed letters and words rapidly with a minimum of information from the surface of the text itself. Beginning readers, on the other hand, are confronted with a complex array of markings which are often difficult to distinguish. Until a beginning reader learns the code of letter-sound correspondences, reading is a baffling task. To understand academic work, then, it is essential to review briefly some of the recent research on how developmental factors affect task performance.

Research on general cognitive development (see e.g., Brown, 1975; Paris, 1975) as well as development within content areas (e.g., Bereiter, 1980) indicates that mature students are selective and efficient in using available cues to extract information relevant to accomplishing a task, and this efficiency increases as they become familiar with a task. Less mature students, on the other hand, attend to a broader range of stimuli and are less likely to select and process information to fit the demands of a particular task (see Pick, Frankel, & Hess, 1975). This is not to say that young children are incapable of understanding tasks or adjusting strategies to meet task demands. Investigators in the field of sociolinguistics have found that children as young as four years old adjust language usage to match the demands of different communication tasks, such as giving an explanation to an adult versus giving the same explanation to a younger child (Pickert & Sgan, 1977; Shatz & Gelman, 1975, 1977). Nevertheless, young children often require a "well-formed" task in order to understand its demands and respond to them appropriately (Simon & Hayes, 1976). In addition, young children often have difficult in using information-processing strategies deliberately (see Brown, 1975 especially). That is, they are able to understand tasks in their daily world and remember a considerable amount about these tasks and their accomplishment. Developmental differences are clear, however, when a task involves deliberate memorizing or the deliberate acquisition of a new schema in order to achieve comprehension of academic content. Young children have what has been called a "production deficiency" (Kreutzer, Leonard, & Flavell, 1975). This mean that they are capable of using certain information-processing strategies but typically do not use them spontaneously and flexibly to match specific task requirements, such as memorizing a list of words or symbols. For such processes to be activated, young children depend upon specific instructions and prompts from the environment.

Ability appears to affect task performance at the level of information processing capacity as well as domain-specific knowledge for doing academic work. As indicated in the expert-novice studies reviewed earlier, less able students typically fail to understand tasks and often focus attention on specific details of an assignment or a problem. As a result, they have little chance of accomplishing the task successfully or of recognizing when or where they have made a mistake. In writing, for example, Perl (1979) found that poor writers concentrated on the immediate problems of what to write next, showed little flexibility in thinking about the writing problem, and attended to editing prematurely. Proficient writers, on the other hand, appear to combine localized thinking with whole-text planning, monitor their own writing processes, and defer revising until the text is closer to being completed (Flower & Hayes, 1981).

In sum, school tasks, even at the level of basic skills, are inherently complex for all students. This complexity is much more severe, however, for young students and those who lack either the information or the skills to understand tasks, process information, or decide when to use the strategies they possess.

Implications for Instructional Policy

Much of the research on cognitive processes reviewed in the previous sections has been conducted with an eye toward identifying ways to improve instruction. As a result, research reports often contain discussions of how findings can be applied to designing instruction, and some attempts have been made to test experimental instructional programs derived from cognitive principles. Although considerably more basic and applied research in instructional psychology is needed, there are some promising directions which warrant consideration here. What follows, then, is a brief discussion of the way instructional designers conceptualize the task of improving instruction.

Direct instruction in cognitive processes. One of the most common reactions to results of research in cognitive science is to recommend direct instruction in the processes used by expert readers, writers, mathematicians, or scientists (see Anderson, 1977; Glaser, 1978; Resnick & Ford, 1981, for general discussions). For example, several investigators have been working to devise and test methods for teaching children to monitor their own comprehension and make inferences while reading (Collins & Smith, 1980; Hansen, 1980; Pearson & Camperell, 1981; Tierney & Pearson, 1981). Although emanating from field studies in classrooms rather than laboratory analyses of cognitive processes, proposals for direct instruction have also become prominent in early childhood education (Becker, 1977) and research on effective teaching (Rosenshine, 1979). In essence, direct instruction means that academic tasks are carefully structured for students, they are explicitly told how to accomplish these tasks, and they are systematically guided through a series of exercises leading to mastery. Opportunities for directed practice are frequent, as are assessments to determine how well students are progressing and whether corrective feedback is needed. From this perspective, the role of cognitive science is to define the processes underlying subject matter competency so that programs of direct instruction can be designed to foster these processes in students and thus improve the quality of academic work.

The research cited above has certainly indicated that direct instruction can be effective for some outcomes. Nevertheless, direct instruction is not a universal panacea for teaching all subjects to all students at all levels of schooling. (It is doubtful that such panaceas will ever exist.) And there are at least three important considerations which are relevant to defining the substance of direct instruction and understanding its limitations.

A first consideration is that direct instruction may not be possible in some areas because the processes which have been identified cannot be communicated in terms which are understandable to learners at a particular level of development or ability. One example of this is Groen and Resnick's (1977) study, mentioned earlier, of the invention of algorithms by students. They found that the communicable algorithm for addition (count out m blocks, count out n blocks, and then count the combined set) was cumbersome for computations. The invented algorithm (begin with the larger number and count the smaller number to get the answer) was easy to use and was mastered by most students without instruction. At the same time, it was very difficult to teach this algorithm directly to students. The investigators argued that the original instruction was successful for its indirect rather than direct effects, that is, it established a chain of thinking which led students to invent a useable computational routine which could not be taught directly.

A second consideration is that many processes that experts use, especially in academic disciplines at the secondary level, have not been identified. In the field of literature, for example, work on underlying processes for understanding fiction and poetry is just beginning and the processes are likely to be difficult to communicate directly. If these subjects are to remain in the curriculum--and few would recommend that they be abandoned--then some alternatives to direct instruction are obviously necessary. There is even some hint that perhaps the processes which define expertise cannot be completely identified. Simon (1979) has reviewed evidence that experts in such areas as chess and physics seem to have mastered thousands or tens of thousands of "productions" (i.e., condition-action associations) in their fields. At the present time only several hundred of these productions have been defined with sufficient clarity to permit programming on a computer. The typical textbook chapter in physics, for example, contains about a dozen or so productions. These figures suggest that there are certain inherent limitations to the application of direction instruction to achieve mastery of advanced academic work.

A third consideration has to do with the specificity of the content or focus of direct instruction. One clear finding of cognitive research is that processes operate at different levels. For example, planning for writing ranges from thinking about individual sentences to monitoring one's own writing processes and making decisions about a goal structure for an entire text (Flower & Hayes, 1981). Similarly, memorizing a list of words involves specific routines for rehearsing items as well as broader "metacognitive" operations involved in decisions about which strategies to use and when mastery has been achieved. Finally, solving problems in mathematics and physics involves not only skill in specific computational routines but also an ability to represent problems accurately and select solution strategies appropriately.

Research on performance differences has also indicated that novices, young children, and low ability students target their attention on specific details and lack the strategies and the higher-order executive routines which enable them to understand tasks or construct goals structures and general plans necessary to accomplish them without strong guidance.

Available training research suggests that direct instruction which concentrates on specific operations for accomplishing a task will produce immediate effects, but it is not likely to engender the knowledge structures or strategies required for the flexible use of these operations. A series of training studies by Brown and Campione (1977, 1980) have provided especially important insights into the effects of specificity in direct instruction. They began with a remedial program focusing on teaching young, low ability children to use memorization strategies. The evidence from several sources had suggested that such learners have a production rather than a capacity deficiency: that is, they are able to use mnemonic strategies but, in contrast to high-ability children, they do not use them spontaneously. With prompting, low ability children will use mnemonic strategies, but this improvement is temporary, lasting only while the instructional prompts are available. Moreover, they do not use the memorizing strategies flexibly to transfer to other memory tasks for which prompts are not supplied. There in other words, a "heart pacer" effect in which performance is maintained only because the instructional program does most of the work for the students. The investigators found that durability could be increased through training in specific memorizing strategies, although the amount of training required was much greater than originally expected. In addition, training to achieve durability reduced flexibility. The skills became welded to the items used in training and did not transfer to new items. Consistent with the general work in cognitive psychology, these findings suggested that low ability children have special problems with access to what they know and the flexible use of that knowledge. In addition, training which is focused on specific memorizing skills does not produce flexibility.

A very similar pattern of findings for specific direct instruction is apparent in research with other populations of students. Asher and Wigfield (1980) reported that specific training for young children in referential communication skills (i.e., the ability to adapt speech to an audience) was effective for immediate performance but the skills did not transfer to new tasks. Mayer and Greeno (1972) found that instructional methods which focus on acquiring specific information or a specific computational procedure result in superior performance on "near transfer" tests which require reproduction of information or solutions to problems similar to those used in instruction. On the other hand, methods which focus on comprehension of information or procedures appears to result in superior performance on "far transfer" tests which require application of concepts and procedures to novel problems. There are, in other words, important qualitative differences in outcomes from methods which aimed at different levels of cognitive processing (see also Martin & Saljo, 1976).

This case can also be made for the specificity of corrective feedback. Research on "buggy" algorithms suggests that errors are often the result of systematic procedures which have the appearance of correct algorithms and which often work for a restricted range of probelms. To correct a specific mistake without attending to the higher-level cognitive processes which led to the error is not likely to be effective. Indeed, Perl's research indicates that a focus on specific errors can be detrimental. She found that unskilled college writers, apparently as a result of years of teaching which emphasized correct spelling and syntax, concentrated prematurely on editing to the extent that it interferred with other writing processes.

These findings support the view that direct instruction focusing on specific skills alone is not likely to have long-term consequences unless instruction in higher-level regulatory processes is also provided. In other words, direct instruction which is likely to improve the quality of academic work must be oriented toward processes which generate meaning rather than routines or "surface algorithms" (Davis & McKnight, 1976) which are used without an understanding of what the procedure does or why it is applicable to a particular situation (see Good, 1982). Emig (1981) has described the latter type of thinking "magical" sin e students have no sense of why the routines they are using work.

In a redirection of their research, Brown and Campione (1977) produced some promising results for training in higher-level cognitive operations: little durability was achieved for young children but some flexibility was evident among older learners. Some successes have also been found for direct instruction in making inferences in reading (Hansen, 1981) and estimating answers in arithmetic (Reys & Bestgen, 1981). Two intriguing (although largely untested) programs have also been developed in writing which provide practice in higher-level processes that frequently elude unskilled writers who never get past the immediate obstacles of creating words and sentences. Rubin (1980) has developed a "Story Maker" which enables pupils to create stories by selecting from prewritten story segments. Along similar lines, Scardamalia, Bereiter, & Woodruff (1982) have devised a computerized system for writing essays by selecting from among prewritten sentences.

It is important to realize, however, that direct instruction in higher-level processes and knowledge structures will probably take a long time and have fewer immediate effects. Nussbaum and Novick (1982) found, for example, that a detailed and intensive instructional program designed specifically to modify preconceptions which interfere with learning a science concept was only moderately successful in achieving its objectives. They concluded that the naive scientific ideas of students evolve rather than change abruptly, a pattern which is also true of ideas in the scientific community itself.

Indirect instruction in cognitive processes. The push toward higher-level processes and meaning or understanding places direct instruction in a territory that is usually occupied by what might be called "indirect instruction" (see Joyce & Weil, 1972, for example). Such instruction emphasizes the central role of self-discovery in fostering a sense of meaning and purpose for learning academic content. From this perspective, students must be given ample opportunities for direct experience with content in order to derive generalizations and invent algorithms on their own. Such opportunities are clearly structured on the basis of what is known about an academic discipline and about human information processing. However, the situations are only partially formed in advance. Gaps are left which students themselves must fill. In other words, the instructional program does only part of the work for students to open up opportunities for choice, decision making, and discovery.

(See Shulman, 1970, and Resnick and Ford, 1981, for good analyses of the contrast between direct and indirect methods.)

One example of indirect instruction (although the authors would probably not use this term) is the work of Graves and his colleagues in children's writing (see Graves, 1979; Calkins, 1980; and Sowers, 1979). In this project, the development of writing is viewed as a three-phase processes beginning with playfulness and spontaneity as children "mess around" with words, followed by planning which emphasizes form and correctness, and then a rediscovery of playfulness. To provide opportunities for these phases to evolve, teachers are advised to allow students to select their own topics and forms of writing (letters, essays, descriptive paragraphs) and to be free from an excessive emphasis on correctness of spelling and syntax.

An emphasis on invention in learning is certainly consistent with the basic premise in cogitive psychology that knowledge and understanding are "constructed" by individuals. But, as Resnick and Ford (1981) point out, there is less evidence that indirect instruction is the most suitable or efficient way to obtain this outcome deliberately. Two factors seem to limited the applicability of indirect methods. First, the ability level and background of the students are likely to be an important influence on the effectiveness of indirect instruction. In a comprehensive review of research on the way aptitudes of students interact with instructional methods, Cronbach and Snow (1977) found that high ability students profited from unstructured teaching conditions which allowed them choices in organizing and interpreting information. Low ability students, on the other hand, did not do well under these unstructured or indirect methods. One possible explanation for these findings is that lower ability students lack the general understandings and processes which enable them to formulate their own generalizations or procedures necessary to accomplish academic tasks under indirect conditions. As a result, the "treatment" does not actually occur, that is, they do not have the opportunity to practice higher-level operations.

Second, invention does not automatically lead to useable procedures or an understanding of concepts and principles. As indicated earlier, students also invent "buggy" algorithms as they encounter obstacles in learning. Thus, while increasing the opportunity for invention, indirect teaching also increases the chance for students to develop erroneous solution strategies and misconceptions of content. Special attention in indirect teching must be given, therefore, to monitoring and correcting the inferences students actually make.

Summary. The existing research in cognitive psychology leads to the following general recommendations for improving the quality of academic work:

1. Direct instruction in identified cognitive processes and knowledge structures is probably more appropriate than indirect methods for teaching novices, low ability students, and pupils in the early elementary grades.
2. Direct instruction which is focused on specific skills is likely to have few long-term consequences unless combined with instruction, either direct or indirect, in higher-level executive processes and knowledge structures

for representing tasks and selecting solution strategies. Thus, instruction in decoding needs to be combined with instruction in comprehension monitoring to foster an ability to read independent. If specific teaching is done in isolation, it can produce either magical thinking or an excessive concern for details, both of which interfere with task accomplishment and learning.

3. Indirect instruction is one way of providing practice in higher-order executive routines and the use of knowledge structures to represent problems. Indeed, some degree of "unstructuredness" is essential even in direct instruction to ascertain whether students really understand how and when to use their knowledge and skills. In other words, explicit signals for solution strategies obviate the need for employing executive routines and thus students are not able to practice these higher-level processes or demonstrate mastery of them. In addition, many operations which constitute expertise in academic areas have either not been identified yet or are difficult to formulate into clearly teachable propositions. In such cases, the only alternative is to allow students to experience content so that they can invent procedures and construct knowledge structures on their own. Such experiences obviously need to be structured in ways which seem at least logically related to intended outcomes so that invention will be productive.

4. Resnick and Ford (1981) have observed that "Transitions in competence that emerge without direct instruction may be more common in children's educational development than we have thought up to now" (p. 82). That is, students invent their own algorithms and conceptions of content whether instruction is direct or indirect. This propensity to invent can have both advantages and disadvantages. As indicated, invention enables students to learn routines and concepts that are difficult to teach directly. At the same time, invention can lead to "buggy" algorithms and misconceptions of content. This possibility underscores the central role of corrective feedback in learning and the need to base that feedback on an understanding of the processes that lead students to make mistakes.

5. Finally, accomplishing academic tasks is not solely a matter of general cognitive processes. Especially in the upper grades, students need domain-specific knowledge in a discipline to do academic work.

Academic Work in Classrooms

To this point academic work has been discussed in isolation from the classroom context within which it is normally carried out. This isolation is clearly artificial, and this artificiality is especially serious if one is interested in improving classroom practices. As Neisser (1976) has observed, "no change can have 'controlling,' or predictable, results unless the relevant sector of the world is well understood" (p. 183). To remedy this situation, the discussion now turns to classroom studies. Traditionally classroom research has concentrated on isolating teaching practices which are associated with effectiveness. In recent years, this work has expanded to included detailed analyses of daily life in these settings, and general models which depict the structure of classroom events are beginning to emerge (Doyle, 1980b, 1981). This new work has important implications for understanding the nature of academic work as it is experienced by students and teachers and for identifying realistic ways to improve the quality of that work.

Classrooms as Groups

One central fact of academic work in classrooms is that it occurs in a group. And this fact has major consequences for both teachers and students, consequences which influence directly and indirectly how work gets done. Some of these effects are reviewed briefly in the following sections.

Teachers and classroom management. Because classrooms are groups, teachers are faced with the task of organizing students into working units and maintaining this organization across changing conditions for several months. In addition, they must establish and enforce rules, arrange for the orderly distribution of supplies and materials, collect and evaluate students' papers, pace events to fit bell schedules as well as the interests of students, and respond rapidly to a large number of immediate contingencies. And all of these functions must be performed in an environment of considerable inherent complexity and unpredictability.

Doyle (1979a) has argued that the immediate task of teaching in classrooms is that of gaining and maintaining the cooperation of students in activities that fill the available time. Activities include such arrangements as seatwork, lectures, discussions, tests, and the like. In general, 60 to 70 percent of class time is spent in seatwork in which students complete assignments, check homework, or take tests. In addition, students spend approximately 20 percent of the day in transitions between activities or classes, waiting for fellow students to finish, and other forms of noninstructional classroom business. Rosenshine (1980) contends that this latter figure is constant across classes of high and low achieving teachers and is probably a fixed effect of the organizational structure of schools.

Achieving cooperation is in part a matter of a teacher's attractiveness to students--studies of student evaluations of teachers suggest that students respond to an instructor's general culture and enthusiasm (Kulik & McKeachie, 1975). But cooperation, especially at elementary and secondary levels, also varies with the activity being used (Kounin & Gump, 1974), the types of students being taught (Metz, 1978), the task students are required to accomplish (Morine-Dershimer, 1982; Redfield & Roenker, 1981), and the teacher's skill in managing activities as they are being carried out (Emmer, Evertson, & Anderson, 1980; Evertson & Emmer, in press). Teachers at these levels must, therefore, be adept in selecting and arranging activities and in monitoring and pacing classroom events (Doyle, 1980a).

All of this suggests that in classrooms teachers are required to think about more than academic tasks in planning and conducting instruction (see Clark and Yinger, 1979; Doyle, 1979a; Shavelson and Stern, 1981). In addition, there is evidence that a failure to attend to organizing and managing classroom groups can lead to a breakdown of academic work with predictable consequences for student achievment (see Brophy, 1979; Good, 1979). Classroom management, in other words, is a central part of the task of teaching in classrooms.

Students and classroom groups. The social nature of classrooms also has consequences for students in at least two areas related to academic work. The first area concerns the social and interpretive competences needed to participate successfully in classroom lessons. Interpretive skill is made necessarily in part by the sheer quantity of information in classrooms. Students are required to attend selectively to information sources in order to define tasks and discover ways in which they can be accomplished (see King, 1980; Morine-Dershimer, 1982; Winne & Marx, 1982). In addition, group-focused instruction is not always responsive to the immediate needs of an individual student. Studies of "participation structures," that is, the organization of turn-taking in group lessons, indicate that access to teacher attention and opportunities to practice academic skills in public is affected by a student's ability to function in social situations and interpret the flow of events in a discussion. For some students the social skills needed for classroom lessons are not necessarily fostered at home or other nonschool settings (see Au, 1980; Cazden, 1981; Mehan, 1979; Philips, 1972; Shultz & Florio, 1979).

A second consequence is that peers serve as important resources for accomplishing academic tasks in classrooms. At one level, peers can be sought out for direct assistance on assignments (Weisstein & Wang, 1978). In addition, Carter and Doyle (1982) found that students were able to rely on a few of their peers to solicit valuable information from the teacher concerning the nature of task demands and how they could be met. In this case peer help served to reduce the announced requirements for academic work.

Once again, the evidence suggests that group conditions are a central part of the process of doing academic work.

Instructional Materials

A large amount of classroom time is structured around printed materials. Indeed, many "lectures" actually consist of a teacher going over content contained in a textbook. In addition, students spend two-thirds of their time in elementary and many secondary classes doing seatwork with printed exercises. Recent research has provided useful information about the inherent complexity and instructional properties of these materials, their match with student ability, and their relation to the content of standardized achievement tests.

Analyses focusing on discourse properties and cognitive demands indicate that school texts are not clearly written and often unwittingly pose complex logical and inferential tasks for students (see Anderson, et al, 1980; Frederiksen, et al., 1978; Gammon, 1973; MacGinitie, 1976). In an intensive analysis of the suitability of eight beginning reading programs for low ability students, Beck and McCaslin (1978) concluded that many of the programs presented information to students in ways that were likely to cause confusion. In addition, the instructional procedures recommended to teachers were often convoluted and unnecessarily complicated for students. In a similar analysis of five basal reading programs, Durkin (1981) concluded that the emphasis was on practice and assessment exercises with little direct instruction in comprehension processes and that many of the topics (e.g., identifying referents for pronouns) were never explicitly connected to reading skills but rather were ends in themselves. She remarked that "One possible consequence is that the children receiving the instruction never do see the relationship between what is done with reading in school and what they should do when they read on their own" (p. 542).

Jorgenson (1978) has provided some naturalistic data on the match between textbooks and students' reading ability in reading and social studies at the third and fifth grade levels. In third grade reading, texts were prepared at several reading levels so teachers were able to match students to textbooks. In actual practice, 61% of the students were assigned to material easier than their ability level. In fifth grade social studies, there was a single text for all students, and 85% of the students were required to learn from printed material that was above their reading ability. Students in reading were able to work independently, whereas students in social studies spent time soliciting help from the teacher and other students.

Finally, Armbruster, Stevens, and Rosenshine (1977) studied the content in three reading curricula and two commonly used standardized tests at the third grade level. They found that the overlap between the texts and the standardized tests was low. The reading curricula tended to emphasize "comprehension skills that appear to require inference, interpretation, identification or relationships, and synthesis" (p. 8). The tests, on the other hand, tended to focus on "factual items entailing locating information in the presented text" (p. 8). In a comparison of topics between fourth grade mathematics curricula and standardized tests, the staff of the Content Determinants project at the Institute for Research on Teaching found that the amount of overlap was often less than half (Freeman, et al., 1980).

Clearly more research is needed to the cognitive demands of classroom materials and ways of making them more suitable for instruction since they play such a key role in academic work. The evidence reviewed here suggests that students may often have difficulty learning with comprehension from the instructional materials they typically encounter in classes. In addition, the tasks posed by texts may not always match those contained in tests of academic proficiency.

The Evaluative Climate of Classes

Academic work in classroom is embedded in an accountability structure defined by Becker, Geer, and Hughes (1968) as an exchange of performance for grades. The term "grades" does not refer simply to marks on a report card, although these are of major significance. Various forms of public recognition for appropriate performance occur in classrooms. Students take tests, complete assignments, answer questions in discussions, and so forth. These answers are labeled by the teacher and these labels are usually available to peers in the classroom and to parents, discussions, and so forth. These answers are labeled by the teacher and these labels are usually available to others in the classroom and to parents, school officials, and others who have not witnessed the performance at all.

Observational studies indicate that judgments about student performance in classrooms are frequent (Jackson, 1968; Smith & Geoffrey, 1968). In a study of first and fith grade classes, Sieber (1979) reported that teachers evaluated conduct publically on the average of 15.89 times per hour, or 87 times per day, or an estimately 16,000 times per year. And Carter and Doyle (1982) found that an elaborate system of "points" (i.e., credit toward the final grade) was associated with academic work in classrooms. By being recipients and witnesses to these judgments, students become very aware of evaluative dimensions and build an evaluative map of a classroom environment (see White, 1971). King (1980) found, for example, that:

> Students seemed desirous of successfully completing tasks in the most efficient manner possible in order to place themselves in an advantageous position for gaining a good mark on the report card. Of necessity, students perceived the teacher to be the mediating influence in achiving this goal and they tended to adapt their behavior with a view to presenting themselves favorably (p. 24).... The report card seemed to be the ultimate though seldom visible goal of most student behavior in the learning process and the implications of this for teaching seemed far-reaching. Students were aware that the taking of a unit test and even the completion of the daily worksheets were directly related to the report card. In this respect the report card motivated students to want to work and learn (p. 34).

This evaluative climate in classrooms connects academic tasks to a reward structure. Answers, therefore, are not just evidence of having accomplished an academic task. They also count as points earned in an accountability system. The function of answers in a reward system adds two important dimensions to the accomplishment of academic work:

1. The answers a teacher actually accepts and rewards define the real task in classrooms. The announced goal of an art lesson, for example, may be to learn to analyze the effects of color on emotions, a task which at least potentially involves comprehension. If, however, the teacher rewards verbatim reproduction of definitions from the textbook, the task can be accomplished by memorizing.

2. The strictness of the criteria a teacher uses to judge answers has consequences for task accomplishment. MacLure and French (1978) have described an incident in which a primary school teacher accepted a broad range of answers, many of which were incorrect, in a discussion of birds that were native to the students' home region. As long as a student named a bird, whether or not it actually live in the region, the teacher praised the response. Other investigators have also reported that teachers sometimes praise "wrong" answers (Bellack, Kliebard, Hyman, & Smith, 1966; Mehan, 1974; Rowe, 1974). In such instances it appears that simply giving an answer, rather than a correct answer, is the task. And if any answer is acceptable (or no answers are required), then the task system itself is in danger of being suspended.

Ambiguity and Risk in Academic Work. Doyle (1979b) has argued that because academic tasks in classrooms are embedded in an evaluation system they are accomplished under conditions of ambiguity and risk for students. Ambiguity refers to the extent to which a precise answer can be defined in advance or a precise formula for generating an answer is available. Such ambiguity does not result from poor explanations by a teacher. Rather, it is an inherent feature of certain types of academic work. Risk refers to the stringency of the evaluative criteria a teacher uses and the likelihood that these criteria can be met on a given occasion. A task of memorizing 50 lines of poetry is low on ambiguity--one clearly knows what the answer is supposed to be--but risk is high (if accountability is strict) because of the factors that might interfere with a successul recitation.

Doyle (1979b) has classified the general types of academic tasks identified earlier in this paper (memory, routine, opinion, and understanding) according to their inherent degrees of ambiguity and risk (see Figure 1). Memory I and Routine I tasks are those which involve the reproduction of a relatively small amount of content (e.g., 10 words on a spelling list) or the use of relatively simple algorithms to generate answers (e.g., addition or substraction problems). Such tasks are low in ambiguity and risk: the answers are clearly identified in advance and the likelihood of being able to produce them is high. Memory II and Routine II tasks also involve reproduction or reliable algorithms, but the amount of content is large (as in the example of 50 lines of poetry given above) or the procedure to be used is complicated (long division or solving quadratic equations). Opinion tasks are high in ambiguity--several answers are possible--but risk is typically low since more than one answer can be correct. Understanding tasks are high in both ambiguity and risk. To have an understanding task, some information about the character of the correct answer must be withheld so that memory cannot be used to accomplish the task. In addition, understanding tasks are often not easily reduced to a predictable algorithm. For example, writing a good descriptive paragraph is not simply a matter of following a series of predefined steps. Rather, complex procedures and higher-level executive processes must be employed to generate a produce or answer. Thus, meeting task demands involves some element of risk unless the teacher is willing to accept any answer as adequate.

There is some evidence that students invent strategies for managing the ambiguity and risk associated with classroom tasks. Several studies of language use in classrooms have reported that student talk is constricted, vague, and indeterminant (see Dillon & Searle, 1981; Edward & Furlong, 1978; Harrod, 1977; Sinclair & Coulthard, 1975). Searle (1975), for example, examined the spoken language of high school students in English, social studies, and physics classes and found qualitative differences between academic and non-academic episodes:

> The talk which resulted from their activities as participants in school work was usually a series of short exchanges [and] was not in itself complete but required either reference to texts or movement.... It would seem that the students understood that there was one kind of talk to be used among themselves and another kind which was suitable for school work (p. 280).

Along similar lines, Graves (1975), in a study of writing in the second grade, found that texts for assigned writing were shorter than those for unassigned writing. This effect was observed under both traditional and open forms of classroom organization. Finally, Rosswork (1977), in a laboratory study in which sixthgrade students were required to generate as many sentences as possible from words in a spelling list, found that students improved performance to meet specific output goals by reducing the number of words per sentence to the minimum established by the experimenter. Rosswork commented that "In some cases, specific goals might lead to inappropriate short cutting..." (p. 715).

The picture painted here is one of caution: students restrict the amount of output they give to a teacher to minimize the risk of exposing a mistake. In addition, restricted output can elicit assistance from others in a classroom. Mehan (1974) reported a cause in which first-grade pupils hesitated in giving answers until either the teacher or another student answered for them. The pupils also gave provisional answers to obtain feedback from the teacher before committing themselves to a single answer. Such tactics can elicit "piloting" from teachers, i.e., a sequence in which the teacher gradually increases the amount of information useful for answering until an answer is virtually given to the student (Lundgren, 1977). One student in MacKay's (1978) study described piloting as follows:

> Yeah, I hardly do nothing. All you gotta do is act dumb and Mr. Y will tell you the right answer. You just gotta wait, you know, and he'll tell you.

There is also evidence that students manage ambiguity and risk more directly by attempting to increase the explicitness of teacher's instructions or increase the teacher's generosity in grading final products. Davis and McKnight (1976) met with strong resistance from high school students when they attempted to shift information-processing demands in a mathematics class from routine or procedural tasks to understanding tasks. The students refused to cooperate and argued that they had a right to be told what to do. A similar reaction to understanding tasks was reported by Wilson (1976) in an alternative high school. Students, in other words, appear to hold teachers accountable for conducting lessons (Brause and Mayher, 1982). After their experience, Davis and McKnight commented that "it is no longer a mystery why so many teachers and so many textbooks present ninth-grade algebra as a rote algorithmic subject. The pressure on you to do exactly that is formidable!" (p. 282).

Carter and Doyle's (1982) study of writing tasks in a junior high school teacher's classes provided insight into how students can manage the demands of academic tasks and what consequences such management has for the character of academic work. Writing tasks typically took several days to accomplish and often placed difficult demands on the teacher and the students. When the teacher introduced writing tasks, the students often asked numerous questions about requirements and the nature of the final product, even though the teacher devoted extra effort to these tasks. Students' questions often delayed the transition from explanations to actually working on assignments and these questions continued to interrupt seatwork. These delays and interruptions produced a choppy flow of events and, in turn, threatened the management of time and activities for the teacher. To avoid management problems and sustain working, the teacher often gave explicit prompts. She also provided opportunities to revise writing assignments, offered bonus points to count toward the final grade, and typically graded written products generously.

All of these actions by the teacher reduced substantially the actual risk associated with writing. In other words, the teacher reacted to immediate management demands by adjusting the requirements for academic work. This adjusting did not occur for grammar or vocabulary tasks which typically involved memory or routine algorithms. In these cases, nearly all the students could participate readily in the tasks with a minimum of instructions or delay.

Classroom complexity and academic work. The analysis presented here suggests that academic work is transformed fundamentally when it is embedded in the the complex social system of a classroom. The character of these transformations can be summarized as follows:

1. Accountability drives the task system in classrooms. As a result, students are especially sensitive to cues which signal accountability (e.g., announcements about tests) or define how tasks are to be accomplished (see Carter & Doyle, 1982; King, 1980; Winne & Marx, 1982). In addition, students tend to take seriously only that work for which they are held accountable. If no answers are required, then few students will actually attend to the content.

2. Answering is the task in classrooms. Because of the key role of accountability, student attention is directed to the answering event itself rather than simply to the content. And it appears that students invent a number of strategies for producing answers in ways that circumvent the information processing demands of academic work:

e.g., copying, offering provisional answers, requesting that the teacher make instructions more explicit or provide models to follow closely, etc.

3. Some tasks, especially those which involve understanding and higher-level cognitive processes, are difficult for teachers and students to accomplish in classrooms. In attempting to accomplish such tasks, students face ambiguity and risk generated by the accountability system. Teachers, in turn, face complex management problems resulting from delays and slow downs and from the fact that a significant portion of the students may not be able to accomplish the assigned work. As tasks move toward memory or routine algorithms, these problems are reduced substantially. The central point is that the type of tasks which cognitive psychology suggests will have the greatest long term consequences for improving the quality of academic work are precisely those which are the most difficult to install in classrooms.

4. Because tasks are administered to groups and performance on these tasks is often evaluated publically, teachers are often under pressure to adjust standards and pace to the level at which most students can accomplish tasks (see Arlin & Westbury, 1976). This again may limit the utility of comprehension tasks which typically require considerable skill to accomplish. Moreover, prompts which are given to lower ability students are also

available to other students who may not need such help. As a result, some students end up working on tasks which are considerably below their abilities. Finally, it would seem difficult to maintain individual accountability in a group setting. It is always possible that a student can copy answers from peers or slip through the accountability system in other ways.

5. The emphasis on management of group contingencies and on answering often appear to focus the attention of teachers and students on getting work done rather than the quality of work. In their analysis of case studies in science education, Stake and Easley (1978), for example, observed that content goals seemed to have little salience for either students or teachers. Students, on the one hand, seemed primarily interested in grades as intrinsically valuable: "They did not think of themselves as mastering a certain body of knowledge, but more as mastering (and of course not mastering) those things being required by the teacher or the test. The knowledge domain was not a reality--it was a great arbitrary abstraction" (p. 15:29). A similar emphasis on getting work done with little understanding of what the content means has been found among elementary school students (L. Anderson, 1981; Blumemfeld, Pintrich, Meece, & Wessels, 1982). Teachers, on the other hand, seemed primarily committed to socialization, to the fostering of proper deportment, work attitudes, and cooperation. In addition, several

investigators have recently noted that teachers spend very little time in classes explicitly telling students how to accomplish academic work. Rather, they assign exercises and then monitor students as they work (see Brophy, 1982; Duffy & McIntyre, 1982).

6. Finally, the classroom makes academic work especially complex for novices, young children, and low ability students, that is, those who are likely to find academic tasks difficult to accomplish anyway. Classroom studies also indicate that low ability and immature students are often grouped together for instruction particularly in reading in the early elementary grades. Such groups are typically difficult for teachers to manage, and the quality of teaching in such groups is frequently low (see a review by Cazden, 1981). Any effort to improve the quality of academic work in schools must necessarily address the problem of teaching effectiveness for these students.

Implications for Instructional Policy

Descriptions of classroom realities often evoke the proposal that the classroom system needs to be replaced or fundamentally altered. Such proposals would not, however, seem to have much merit. Replacing classroom is not likely to happen since there will always be fewer adults than students in schools. Once students are grouped and assigned to teachers for specific periods of time, classrooms are brought into existence regardless of the format for activities or the size and shape of rooms. Whatever alternatives are proposed for classrooms, the need to manage groups of students through time and space and the ambiguity and risk associated with academic tasks remain. And classroom complexities are not simply an effect of students. Although the ability composition of classes influences processes and achievement (see Beckerman & Good, 1981), social effects also operate in classes populated exclusively by high ability students (Robert Davis, personal communication). The central problem, then, is to find ways to make classrooms more productive in face of the realities that exist in such environments. In this concluding section some of the possible ways to achieve this goal are reviewed.

Instructional materials. Classroom studies indicate that teachers often rely on instructional materials to carry the academic task system: students spend a good deal of their time working on exercises and reading passages from textbooks and workbooks. Thus, academic work is defined in large measure by commercially prepared materials. Research also suggests that these materials are often poorly designed and written. As a result, students are sometimes prevented from learning the content because of difficulties inherent in the text rather than in the academic discipline or the basic skill being mastered. It is reasonable to propose, therefore, that careful attention be given to academic tasks in the preparation of instructional materials and that more research be conducted to find ways to design such materials and test their efficacy. Many of the insights about cognitive processes reviewed earlier in this paper are applicable to this design problem. And classroom studies suggest that special attention needs to be given to the design of materials for higher-level comprehension tasks which are often difficult for teachers and students to accomplish in classrooms. It is also necessary to add that such designs need to be done with classroom realities in mind. If not, it is unlikely that the products will be used in the academic program of schools.

Training in managing tasks. As more is known about academic tasks and how they are carried out in classrooms, possibilities for training teachers to manage academic work more efficiently and effectively will increase. On the basis of present knowledge, there are at least two areas which warrant special attention in teacher preparation. First, accountability appears to be a central component in the academic task system. If answers are not required or any answer is acceptable in a particular area, then students are not likely to take the work seriously, especially in the upper elementary and the secondary grades. It would seem essential, then, that teachers learn the importance of accountability and explore a variety of ways in which accountability can be handled creatively in classrooms. Second, teachers need think about academic work in cognitive terms and become aware of the various paths students invent to get around task demands in accomplishing academic work, such as delaying, eliciting overly explicit prompts, etc. With this awareness, teachers can begin to devise ways to sustain task demands and thus have students use the cognitive processes which are intended for task accomplishment.

It is important to reiterate that the tasks which cognitive science indicates are likely to have long-term consequences, such as those involving higher-level executive routines, are probably the most difficult to manage in classrooms. Tasks which leave room for student judgment are often hard to evaluate and have a grater probability of evoking attempts by students to circumvent task demands. Special attention needs to be given to managing such tasks if the quality of academic work is to be improved.

In addition to managing academic tasks, teachers also face the larger problem of establishing and maintaining cooperation in activities. Unless skills in this area are well developed, a teacher will have little time to think about academic tasks or little freedom to arrange classroom events to sustain a variety of task types. Indeed, without highly developed management skills, a teacher is likely to rely on memory and routine tasks which typically elicit cooperation from more students and especially those who are inclined to disrupt activities. Major progress has been made in recent years in understanding how classroom management is accomplished (Doyle, 1980a) and to test procedures for helping teachers learn these processes (Emmer, et al., 1981; Emmer, et al., 1982). Additional research is needed, however, to extend this work toward the management of academic work.

Direct and indirect instruction. Research on effective teaching has generally indicated that, at least in basic skill areas in elementary and junior high schools, high levels of student engagement are associated with high achievement and that direct instruction in which the teacher actively manages academic work is likely to sustain engagement (Rosenshine, 1979). From the perspective of classroom management, direct instruction is likely to be efficient. If academic activities are carefully and clearly organized and the teacher has a central role in the classroom, then he or she will usually be in a position to monitor classrom events and intervene early to stop disruptions. In addition, engagement is generally high in teacher-led instruction so that the task of management will be relatively easy. Indirect instruction, on the other hand, it typically more difficult to manage because of resistance from students and because of the pace and rhythm of events is inherently slower.

As indicated earlier, however, the quality of the time students spend engaged in academic work depends upon the tasks they are expected to accomplish and the extent to which students understand what they are doing. It is essential, therefore, that direct instruction include explicit attention to meaning and not simply focus on engagement as an end in itself (see Good, 1982). Moreover, some curricular areas, especially in the upper grades, may not lend themselves to direct instruction. It is in these areas that special attention needs to be given to task management.

In connection with the concept of direct instruction, Duffy and McIntyre (1982) have noted the tendency to equate teaching with providing opportunities for practice. Thus working is seldom accompanied by explicit instruction in how to do academic tasks. The present analysis indicates that this lack of explicit teaching in classrooms needs to be examined from the perspective of the complex demands of the classroom environment. Explicit teaching for sustained periods of time may well be a difficult activity to manage in classrooms due to a lack of student attention or problems in monitoring a class while explaining. Because explicit instruction often affects the quality of academic work, this area warrants further investigation.

Finally, special attention needs to be given to the quality of academic work for low ability and immature students. These students are likely to find academic work difficult and their problems increase as such work is embedded in a complex classroom environment. Practices which lead to grouping these students together for instruction often increase the complexity of the task environment for the students and create formidable management problems for teachers leading to a lowering of the quality of teaching. Such grouping practices need to be examined carefully and alternatives for working with low ability students in classsrooms need to be explored.

Conclusion. Classroom studies have underscored the extent to which the actual curriculum is realized by teachers and students at the classroom level. At the same time, classrooms are complex settings which are not easily rearranged. And there are pressures on teachers and students to sustain existing forms of academic work which tend to rely on memory and routine tasks. Any changes in the classroom system will continue to face these inherent pressures. Major improvements in academic work clearly depend upon further inquiry into the event structures of classrooms and how work is accomplished in these environments.

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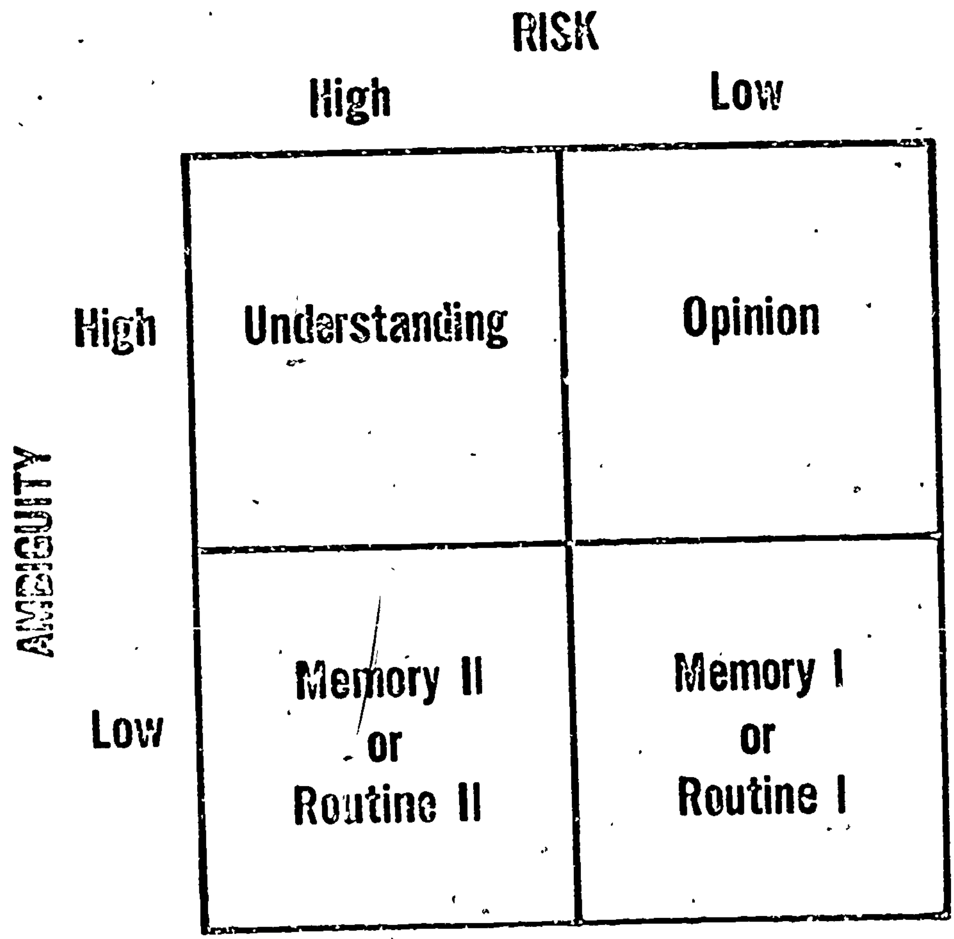

Figure 1. Dimensions of ambiguity and risk associated with academic tasks in classrooms.