ABSTRACT

VERTICAL TRANSFER OF INSTRUCTION BASED ON
COGNITIVE STRATEGIES FOR A SEQUENCE
OF GEOLOGIC TASKS

by

Fred Nelson Finley

In this study an information processing approach was applied to design an instructional sequence which would effectively and efficiently teach students to classify igneous rocks, and to evaluate learning and transfer within the sequence.

This approach involved content analysis to provide a three level description of the detail and structure of the knowledge related to igneous rock classification. The resulting description was in terms of an interrelated set of concepts, task descriptions, and task specific cognitive strategies. The instructional sequence was organized on the basis of compatible cognitive strategies.

The sequence consisted of three tasks. The first task required students to compare the rock samples to a standard. The second task required students to classify the samples using a one variable, three cell classification scheme. The final task required students to classify the samples with a two variable, nine cell, geologic classification scheme.

The design of an instructional sequence which shared common concept and task features was expected to (1) facilitate learning during

instruction, (2) enhance task performance on a posttest, and (3) enhance the transfer of learning to the pretest for a related task. Instruction based on task specific cognitive strategies was expected to enhance learning and transfer to an even greater extent within the task sequence. The availability of the strategies in a student's memory was to serve as a mechanism which would enhance learning and transfer.

Randomly selected students were assigned to three treatment groups. The Cumulative Strategy group was instructed on a cognitive strategy for each task. The Cumulative Feedback group was given feedback on the correctness of their performance for each task. The Isolated Feedback group consisted of two sets of students. Each set was given feedback instruction for the second or third task only.

Observations of student behavior were made using coding systems based on the cognitive strategy models. Scores were defined to reflect students learning, use, and transfer of the strategies during the instruction, the posttests, and pretests respectively. Additional scores reflected the accuracy of performance and the amount of instruction necessary to learn to perform the tasks. Data analysis (1) described the learning, use, and transfer of the cognitive strategies by students, and (2) evaluated effects attributable to instruction on the task sequence and effects attributable to strategy based instruction by comparing performances of the treatment groups.

The findings of the study were:

(1) Students learned the task specific strategies during instruction.

(2) The students used components of the strategies they had been taught during posttests, and transferred strategy components to the pretests for the next closely related task. Students did not use or transfer the complete strategies extensively.

(3) The performance results related to instruction on the task sequence and the strategy based instruction were mixed. Significant differences occurred at important times during the instructional sequence, but did not occur consistently. The differences were generally not dramatic.

(4) The detailed representations of the knowledge students were to learn in conjunction with an information processing view of human thinking proved useful. The descriptions of the knowledge and learner guided both the selection and sequencing of the content for instruction. The detailed representation of the knowledge led to collecting data which provided substantial insight into the manner in which students used and transferred that knowledge.

(5) The experimental design and the thoroughness of the observations generated a large volume of data which proved difficult and costly to

collect, manipulate, and reduce to meaningful scores. Smaller scale studies would have provided some of the important findings more efficiently.

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To Alice and Ken

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CHAPTER I

THE PROBLEM

A major expectation of all schools is that students will learn what they are taught and transfer what they have learned to more complex situations. Science education students are expected to learn and to transfer knowledge and skills of the science disciplines. As the body of knowledge which constitutes any one discipline is large, those engaged in instructional design have two major responsibilities. The first is to select that knowledge which is most central to solving the problems of the discipline. The second, the problem of this study, is to design instruction to maximize the ease of learning and to enhance transfer of that knowledge to new, often more complex, situations. In addressing these responsibilities instructional designers must be able to describe the knowledge to be taught, to model the thinking of the learner, and to describe the manner in which the design should be accomplished.

There are two components to the thesis of the study.

(1) Instruction for the precursor tasks of a sequence will enhance performance of later tasks when the sequence is designed on the basis of analyzing the structure of the knowledge to be learned and an information processing view of human thinking.

(2) There will be a facilitative effect of instruction based on task specific cognitive strategies within the task sequence.

The second statement was the major focus of the study.

The specific undertaking was to design an instructional sequence which would effectively and efficiently teach students to classify igneous rocks and to evaluate learning and transfer within the sequence. Students were given a number of rock samples to classify using a two variable classification scheme. These two variables were the size of the mineral grains and the relative amount of light and dark grains in the individual samples. The two variables were crossed, resulting in a 3 X 3 matrix defining nine classes of igneous rocks. Each sample must be correctly placed in one of the nine classes. Rock classification was selected as particularly important to geologists in addressing a large number of problems within the discipline. The instruction was designed to facilitate the initial learning of the geologic classification and there should be direct evidence of transfer within the instructional sequence.

For this study the following were done to meet the responsibilities cited:

I. The knowledge to be taught was described in detail. The description included the information to which the student could make explicit reference, and that knowledge which was implicitly required to classify the rocks. This knowledge was described in terms of the constructs of the discipline.

II. A psychological model was prepared which specified how knowledge of the discipline could be used in the student's reasoning as he classifies the rocks.

III. The design process was made explicit. This included the way the knowledge of geology and a model of a thinking student were combined to result in an effective instructional procedure.

With respect to each of these undertakings, past arguments within science education point to several considerations or problems. The following section briefly describes those arguments. The second section characterizes the present literature which will be considered. The final section presents an overview of the study including specific research questions.

Arguments Related to the Design of Instruction

Science education over the past twenty years has debated what students should be taught and how that information could be organized to facilitate learning and transfer. As pointed out by Shulman and Tamir (1973), much of this discussion has focused on the notion of structure. Within this debate two lines of thought, often intermingled are important. The first is epistemological, the second psychological.

A third consideration is the process of designing the instruction. This has not been an explicit topic in the science education literature. These three considerations are outlined below.

The Knowledge to be Taught

The epsitemological arguments focused on what should be taught. The traditional answer had been to select the scientific laws, facts, principles, and definitions which were considered the stable truths of each discipline. The textbook served as the collection of content to be learned. The more recent response has been "emphasis on the nature, structure, and unity of science, and on the processes of scientific inquiry" (Klopfer, 1971, p. 565). In particular, the "processes of science" such as hypothesis formulation, data collection, classification, and inferring were constrasted with the previous "content" notion of what should be taught.

Even though discussion of the value to be placed on content or process has abated, issues of what should be taught are unresolved. Most science educators would now agree that both content and process should be taught. However, the descriptions of how content and process are related have not been fully developed. Schwab has begun the description of these relationships using the parallel terms substantive and syntactic structures of the disciplines.

Schwab's work described the nature of disciplines. For Schwab "the structure of a discipline consists, in part, of a body of imposed conceptions which define the investigated subject matter of that discipline and control its inquiries," (1962, p. 199). He further describes the types of structures named above. The first, substantive structures, is "a body of concepts--committments about the nature of the subject matter functioning as a guide to inquiry." The second, syntactic structures, is "the pattern of its (the discipline's) procedure, its method, how it goes about using its conceptions to attain its goal" (Schwab, 1962, p. 203). It is important to note that Schwab views these structures as "interrelated, capable of distinction in theoretical discourse but never in practice" (Shulman and Tamir, 1973, p. 1102). He further claims that the structures are particular to each discipline. Structures, be they content or process, which cut across disciplines should not be expected. This is an important point of Schwab's work unfortunately ignored by many curriculum developers. The integrity of the structures of a given discipline must be maintained, lest incomplete or inaccurate knowledge be included in curricula.

Schwab's work clearly calls for the identification and description of specific substantive and syntactic structures. However, there are few detailed analyses of this type in the science education literature. One reason for this may be the lack of analytic models to help describe the intersection of syntactic and substantive structures. The structures of a discipline are many and complex. To do the analyses which should precede instructional design such analytic models are needed to simplify and organize the resultant information. Analysis and description of the knowledge to be taught not only avoids misrepresentation of the knowledge, but provides the designer with the major structures to be used in the design process.

Psychological Views of Learning and Transfer in Science Education

The second critical area for the discussion of structure was psychological. The major question was how to best facilitate the learning and transfer of knowledge structures. The discussion centered on what knowledge can be best taught and the development of optimal organization of that knowledge. These questions were approached from a number of psychological perspectives. The views most relevant to the present work are represented by Bruner and Gagné.

For Bruner (1963) structures of a discipline were described as the principles and generalizations which related a range of phenomena. Bruner expected such structures to serve as mechanisms of learning and transfer. This kind of knowledge would be more easily retained and transferred more broadly. Furthermore, instruction to teach such structures was to proceed in such a way that students discover those general relationships. This was based on the view that learning is an "act of discovery" requiring the recognition of new knowledge, followed by the cognitive reorganization and verification of that knowledge (1961).

Gagné (1970) claimed that instruction should be hierarchically ordered. The final task learning had to be supported by the prerequisite skills of simpler types of learning. The learning of principles was dependent on learning prerequisite rules which in turn depend on the learning of necessary concepts. Gagné posits such hierarchically organized skills, called capabilities, as internal to the learner. The capabilities are described in terms of the behaviors the learner can perform.

The work of Gagne, Bruner, and others established the necessity of considering the learner when designing instruction to facilitate learning and transfer.

Bruner's concept of structures (principles and generalizations from a discipline) as mechanisms of transfer and the "act of discovery" provide two guidelines for curriculum design, but little in the way of detailed description. The first points to considering that the nature of the knowledge influences the manner in which the learner uses that knowledge. However, Bruner does not propose a way these structures can be systematically identified and described. The "act of discovery" notion clearly implies that there is an important internal cognitive processing of newly recognized knowledge. However, little of how the knowledge structures are reorganized is specified. With a model of the way knowledge is cognitively processed, a great deal more information about the learner would be available to the curriculum designer.

Gagne presented a more precisely defined and detailed set of constructs than did Bruner. This resulted in a more complete description of the internal and external conditions of learning. However, the description of internal capabilities only in terms of behaviors that can be observed limits the richness of this description. Little is known of how knowledge is directly used or altered as an individual attempts to complete a task. By tying the psychological descriptions so closely to the overt behaviors, little is known about the dynamics of the thinking of an individual. What is required for instructional design is a more dynamic, precisely specified model of human thinking. This should describe the processing of the available knowledge structures and reflect in detail the observable performance.

The Design of Instruction

Different conceptions of instructional design have been implicit in elementary and secondary science education curricula. The notion that instruction is designed by deduction from a single psychological theory has been prominent in elementary school curricula. For example, various psychological perspectives greatly influenced the Elementary Science Study (Bruner) and Science-A Process Approach (Gagne). Although much more attention was paid to the nature of the subject matter in the design of the Science Curriculum Improvement Study, the work of Piaget was highly influential. As Shulman and Tamir point out, this is inadequate to the task. "Psychological theories of learning and cognition remain far too weak a foundation to support any entire curricular program. No single theoretical formulation has yet demonstrated sufficient comprehensive validity to be trusted to this task." (1973, p. 1138).

At the secondary level the reverse problem was the case. Knowledge related to learning and cognition was not fully utilized. Instead, extensive reliance was placed upon the structure of knowledge. New courses were designed in biology (Biological Science Curriculum Study), Chemistry (CHEM Study), and Physics (Physical Science Study Committee). These attempted to reflect more adequately the nature of science disciplines than had the traditional approaches.

The result of this single factor design approach has been that relationships between the knowledge to be learned and the psychological mechanisms of learning are unspecified. The design process should integrate the epistemologic information gained from the careful analysis of the structure of the disciplines and our knowledge of the learner as he exhibits various performances. Without such integration, information valuable to the designer is lost, often in the confusion of psychological and epistemologic constructs. A design process such as this requires epistemologic descriptions and psychological models which are compatible.

Components of the Present Research

The present work attempts to develop and evaluate an instructional sequence designed to facilitate learning and transfer. The design incorporates the detailed analysis of the knowledge structures and a compatible psychological model of the way students use the available knowledge to complete specific tasks. To do this the work of Schwab is extended, and a psychological model of cognitive performance, richer in descriptive power than models proposed by Bruner and Gagne is utilized. The following explanation briefly characterizes the model proposed by Smith (1974) for the analysis of disciplinary structures and the information processing psychology of Newell and Simon. The major tenets of the design process adopted from the Science of the Artificial by Herbert Simon (1969) are also described.

Analyzing the Knowledge: The Content-Task-Strategy Model

The model used in this study for the analysis of the disciplinary structures was developed by Smith to represent specified domains of learning in terms of concepts, tasks, and strategies. When taken together the resulting description represents the structure of some portion of a discipline (Smith, 1972, 1974). This model is particularly appropriate to meet the needs of this study. The descriptions of the knowledge to be taught are constituted in such a way that Schwab's warning to maintain the relationships between the structures of the discipline is followed. Both substantive and syntatic structures and the relationships between them are made explicit in these descriptions.

He has proposed three levels of analysis in the description of the learning objectives. Smith describes these levels of analysis as follows:

> "Content analysis involves (1) the identification of the types of conceptual systems characteristic of a discipline or subdiscipline, (2) the formulation of a paradigm or analytic network which represents the structure of each type of system and (3) the comprehensive identification and cataloging of the conceptual systems of discipline according to the analytic network they exemplify.
>
> Task analysis involves the identification or performance requirements relevant to a specific type of conceptual system. These requirements or tasks are described in terms of the corresponding analytic network.
>
> Skills analysis identifies alternative information processing strategies by which tasks can be performed. These are descriptions of behavior at the psychological level and provide the basis for planning and predicting transfer among tasks." (1974, p. 2)

The content analysis is viewed as a detailed description of Schwab's substantive structures. Task and skills (or strategy) analysis, when taken together, describe important aspects of the syntax of the discipline. The tasks specify what is done with the substantive structures. The strategies described in psychological terms the way those tasks are carried out.

In general, Smith views learning and transfer to be facilitated in an instructional sequence by the presence of shared concept, task, and strategy components. He argues particularly for the facilitative effect of the strategy component as follows:

> "The transfer effects of learning several tasks probably depend heavily on the strategies the student learns to use in performing both original and transfer tasks. This suggests that the design of instruction to optimize positive transfer must consider strategies which the student learns to use in performing the tasks." (1974, p. 11)

The major focus of this study is the facilitative effect of instruction based on task specific cognitive strategies in a sequence of successively more complex tasks.

Information Processing Psychology: A Dynamic View of the Learner

The basic tenet of the information processing theories is that human beings are adaptive systems which behave according to the nature of the task with which they are confronted. Thus, the field of information processing psychology considers both the structure of the tasks to be performed and the cognitive processing of available information. This viewpoint is adopted for the present work as it offers a potentially rich description of a learner completing a task, and, accordingly, more information useful in instructional design.

In the design of instructional sequences the knowledge to be learned is specific to and inherent within a discipline. Using the model proposed by Smith major structural components can be described in terms which represent the structures of the discipline. Within the information processing framework, such description can be used to describe what is called the task environment. This is the information to which the learner can make explicit external reference. We can also represent the necessary and sufficient knowledge from the discipline which is required within the learner to complete the specified performance. This additional knowledge refers to the content of the problem space, the mental world in which the learner performs sequences of cognitive operations with available knowledge to solve a given problem.

The task environment and problem space are closely related. The structure and information in the task environment, in conjunction with the existing knowledge of the learner, determines the problem space the learner adopts. Certain structural features of the task environment will be predominantly represented in the problem space. The problem space which is constructed by the problem solver may or may not be appropriate for solving a given problem. This can be due to the influence of previous experience and missing knowledge. It is reasonable to expect that if the problem space contains relevant, well organized information, the probability of correct task performance will be high. In particular, if the conceptual knowledge necessary for a specific performance and strategies which process that knowledge in an organized way are available, and likelihood of correct performance is increased. Learning and transfer phenomena may be explained in terms of the availability in memory of concepts and strategies which can be utilized by a learner for performing a given task.

The Design Process

Simon views design as a science in its own right. He describes design as the development or courses of action which change existing situations into preferred ones (1969, p. 55). The result of such design is an artifact. The designer uses (1) knowledge of the goals which the artifact is to meet, (2) knowledge of the workings of the inner environment of the artifact, and (3) knowledge of the outer environment. The premise is that to the extent the inner environment of the artifact is appropriate to the outer environment in which it operates, the goals for the artifact will be attained. This view is extended by Simon to describe the human problem solver as an artifact in that he is an adaptive system which can be changed and modified by learning.

From this viewpoint instructional design can be considered a matter of utilizing what is known about the knowledge to be learned (outer environment) and the inner environment of the learner to develop effective and efficient learning experiences.

Design on this basis requires (1) descriptions of the knowledge to be learned (i.e., the outer environment) and (2) a model of inner environment of the problem solver. More particularly, the model of the problem solver needs to include a description of the knowledge and strategies which would constitute a problem space appropriate to the outer task environment and a model of the way the problem solver processes that information. The description of the knowledge taken from a discipline and potential matching problem space is possible using constructs such as those proposed by Smith. Information processing psychology offers rich description of the problem solver.

Overview and Direction of the Study

The epistemologic arguments of Schwab's work imply a need to map a potential domain of learning before design of instruction, lest the selection and representation of knowledge be inaccurate. The integrity of the structure of the discipline from which the knowledge is drawn must be maintained.

An information processing view indicates likewise. The task environment and previous learning interact to generate a problem space the student uses to perform the given task. We need to know what information is given about a problem and what is required to solve it. Without such information the designer cannot forge appropriate instructional procedures.

To design and evaluate instructional sequences, we need to propose psychological mechanisms of learning and transfer. In this study a common set of concepts and, in particular, task specific cognitive strategies, serve this function. The construct of a strategy is psychological, but it is viewed also as a description of a syntax of task performance.

The final knowledge to be learned can be reduced to simpler learning episodes related by common features. These preliminary episodes must be designed and sequenced, taking into consideration these structures of the final learning desired before a high level of performance can be expected.

This study carried out the following:

I. Mapped a potential domain of learning and transfer.

1. A portion of geology was identified as an important structure of that discipline. Specifically, the classification of igneous rocks was selected. This is an important procedure used in solving problems of the discipline.

2. The substantive structures related to the classification were identified and characterized according to the nature of their function in the discipline. This was done in terms of Smith's analytic networks.

II. Proposed possible psychological mechanisms of learning and transfer.

1. Common conceptual structures and task specific cognitive strategies were hypothesized as mechanisms for the learning and transfer of disciplinary structures.

III. Designed a learning sequence across which learning and transfer can be expected to occur.

1. The knowledge to be learned was analyzed to determine precursor learning episodes which

are smaller, less complex components of the final episode.

2. The learning sequence consisted first of learning concepts related to the classification of igneous rocks. Second, the sequence was a series of tasks, ordered according to the expectation that learning a strategy for one task would facilitate learning and transfer in the next task.

IV. Empirically investigated strategy learning, strategy use, strategy transfer, task performance, and learning transfer within the task sequence. For purposes of this study these terms were defined as follows:

1. Strategy learning is the initial acquisition of a strategy inferred from students actions during the instructional trials.

2. Facilitation of learning consists of fewer trials to criterion compared to an appropriate control group. Trials to criterion indicate the amount of instruction necessary to learn to perform a given task.

3. Strategy use is the generalization of the strategy to new elements (rock samples) which is inferred from students actions on the posttests.

4. Task performance is the effect of previous instruction on the accuracy of student performance in the posttests for a particular task.

5. Vertical strategy transfer is the use of the strategy for a previous task during the pretest attempt to complete a subsequent task in the sequence.
6. Vertical learning transfer is the cumulative effect of the previous instruction on the accuracy of student performance during the initial pretest attempt to complete the next task in the sequence.

The unique aspect of the instructional sequence is the three dimensional representation of what was to be learned, i.e., the representation of the learning objectives. These were expressed in terms of the following:

(1) interrelated sets of concepts,

(2) task descriptions including the information given to the student and the performance outcome required,

(3) cognitive strategies which are models of the cognitive processes a student could use to systematically act on the information available in completing the task.

The relationships among these descriptions of what was to be learned were detailed in terms of common or compatible features in each dimension.

The derivation, description, and organization of the objectives into an instructional sequence were based on the related features of each of these three dimensions of representation. It was further based upon the chosen design approach. The intent was to design instruction which would generate an inner environment (problem space in the learner) potentially sufficient in an encounter with the given outer environment (the task the learner is to complete).

The analysis of igneous rock classification resulted in a description of the concepts and task requirements which characterize the outer environment. It further resulted in the identification of concepts and potential cognitive strategies which would be in a problem space appropriate for the task environment. Given the detailed three dimensional description of the final task, the design continued to develop related preliminary tasks which reduced the complexity of the learning. The closely related tasks are progressively smaller components of the final task. The use of smaller numbers of identical concepts and less complex subroutines of the strategy, both taken from the final task, served as the basis for these preliminary tasks. The major features of the final task were maintained as smaller, logically related chunks of information to be learned. The attempt was to (1) optimize the amount of knowledge acquired during a single instructional episode and (2) to facilitate the formation of a few large chunks of information which could be processed from the limited capacity short-term memory.

From this perspective, learning to solve a particular task was considered the accumulation of the necessary knowledge and strategies so that a problem space appropriate to the task is generated upon encounter with that task. Learning will be facilitated according to the degree to which a match between the problem space and task environment is attained. The problem space is appropriate to the task environment to the extent that concepts and strategies of the learner fit the features of the task. It can also be expected that transfer of learning to a new, more complex task can be expected if the previous task shares common structures, and the learner has those structures available for use on the new task.

RESEARCH QUESTIONS

The preceding section outlines the steps taken to meet the epistemologic and learning considerations previously described. The following is the translation of those considerations into researchable questions.

I. Strategy Learning:

When instructed in a specific strategy within a task sequence, can the student learn to perform the task using that strategy?

II. Strategy Transfer:

Does a learned task-specific strategy transfer to a more complex task within a task sequence, that is, will a student automatically utilize the strategy learned for a precursor task in the uninstructed attempt to perform a related more complex task?

III. Strategy Use:

Following instruction on a task within a task sequence do students use the taught strategy to perform the task?

IV. Does strategy-based instruction improve the learning of a vertical sequence of tasks? More specifically:

A. Learning Transfer:

Does strategy-based instruction enhance the transfer of learning within the task sequence?

B. Facilitation of Learning:

Does strategy-based instruction enhance the efficiency of learning of the tasks within the sequence?

C. Task Performance:

Does strategy-based instruction for the sequence enhance posttest performance within the task sequence accuracy?

The remaining Chapters describe the attempts to answer these questions. The second chapter (1) describes epistomologic, psychological and design issues which have been related to the constructing instructional sequences, (2) describes the literature utilized to address these issues, and (3) describes the manner in which the literature was applied in the present study. The third chapter describes the experimental procedures, specific research hypotheses and scores used to answer the research questions. The fourth chapter presents the results of the experiment. The final chapter summarizes those results and intrepretes them in light of the initial premises and limitations of the study.

CHAPTER II

REVIEW OF RELATED RESEARCH

The present chapter reviews the research considered in the development of this learning and transfer study. The chapter can be divided into five sections. The first reviews recent literature in which there have been attempts to describe the nature of the knowledge to be learned. The second reviews recent literature related to the learning and transfer of knowledge as argued by researchers who had a major influence in science education. The last portion of each of these sections reviews in some detail the literature directly utilized in the present study. The third section describes the view of instructional design which guided the development of the instructional sequence. The fourth section is the most important of the chapter as it describes the results of applying the reviewed literature to meet the goals of the study. The section includes the description of the knowledge to be learned in terms of concepts, tasks, and strategies. The final section briefly reviews science education studies and the basic work of Piaget related to multiple classification.

The Structure of Knowledge

Schwab (1962), Phenix (1962), and others have argued that the various disciplines must serve as the sources of knowledge to be included in the curriculum. As noted earlier, Schwab has further argued that the nature of the structures of that knowledge are particular to each discipline. He asserts that the relationship between the substantive and syntactic structures within each discipline must be maintained if the curriculum is to accurately reflect the knowledge to be taught. Taken in total these points argue for a strong epistemologic foundation for instructional design.

The argument for attending to the structure of knowledge has been made for work in both curriculum development and curriculum research. Robinson, in the "Philosophical and Historical Bases of Science Teaching" (1969), asserts that the elucidation of structure has been inadequate and, as a result, has been problematic in curriculum development.

"This lack of precision and comprehensiveness is seductive with respect to many who work in curriculum development because it promises great simplification in the overwhelming task of mastering the manifold realms of scientific knowledge. It creates the illusion of easily grasped solutions rather than hard scholarship for dealing with curriculum problems" (1969, p. 460). Citing Hurd and Rowe, Robinson also argues that research efforts have suffered from a lack of analysis from an epistemologic base: ". . . researchers have lacked well-developed philosophic starting points and have tended to be contradictory, fragmented, and unpatterned" (Robinson, 1969, p. 459).

In concert with Robinson, Shulman and Tamir make the following recommendation, ". . . the structure of the subject matter must. . .

become an explicit facet of research design in the field of instructional research" (1973, p. 1138). A variety of researchers have suggested ways of representing the knowledge to be taught. Many of these views (Bruner, Gagne, Schwab) have served as the basis for the development of particular science education programs.

Bruner called attention to the necessity of attending to the nature of the knowledge. From a psychological perspective he cited four arguments for teaching the "fundamental structure of a subject" (Bruner, 1960).

1) "The first is that understanding fundamentals makes a subject more comprehensible" (p. 23).

2) "The second relates to human memory. . . unless detail is placed into a structured pattern, it is rapidly forgotten" (p. 24).

3) "Third, an understanding of fundamental principles and ideas, as noted earlier, appears to be the main road to adequate 'transfer of training'" (p. 25).

4) "The fourth claim for emphasis on structure and principles in teaching is that by constantly reexamining material taught in elementary and secondary schools for its fundamental character, one is able to narrow the gap between 'advanced' knowledge and 'elementary' knowledge" (p. 26).

For Bruner the fundamental structures were the principles and concepts of a discipline so basic and important that they simplified and made understandable a wide range of related phenomena. Bruner did not specify how the fundamental structures could be described or identified but called for further research on each of these four arguments.

Schwab described the nature of discipline structures in greater detail than had Bruner. His representation of the knowledge to be learned was dependent upon the conviction that "to identify the disciplines that constitute contempory knowledge and mastery of the world is to identify the subject matter of education. . ." (1964, p. 11). On the basis of the review of some four thousand researcher reports, Schwab characterized the disciplines as distinctive in terms of the substantive and syntactic structures which were used to guide their inquiries. This study has been cited by Robinson as the "most penetrating analysis of structure in the literature" (1969, p. 460). However, lest the scope of this work be misinterpreted, Schwab himself has described this work as preliminary investigation "of the nature, variety, and extent of human knowledge" (1964, p. 6). He expected later work to provide the detailed descriptions of specific structures.

Gagne chose to represent the knowledge to be learned in terms of psychological descriptions of the tasks to be performed. The final task was analyzed by asking the question, "What do the students need to know before they can complete this task?" By successively asking this question, learning hierarchies were developed which specified the prerequisite knowledge. The hierarchies described the conditions internal to the learner which are necessary to complete the final task. The task descriptions are in terms of concepts, rules, and principles which are defined as psychological constructs. For Gagne, the concepts, rules, and principles are classes of responses which indicate different types of observable performances.

The final tasks from which the learning hierarchies were derived were to be specified by subject matter specialists. However, from that point on in the development of the hierarchy there is little or no concern for the structure nature or structure of the discipline. Gagne contended that ". . . difficulties in identifying the content of learning would be avoided if care were taken to put the emphasis where it belongs, which is on the attainment of the learners" (1970, p. 244).

More recently within science education has been the work of Klopfer in the Handbook of Formative and Summative Evaluation (Bloom, Hastings, Madaus, 1971). Klopfer used both desired student behaviors and a range of content for elementary and secondary schools to generate a matrix representing science knowledge. The student behaviors were in part derived from the Bloom Taxonomy of Educational Objectives but also focused on categories relating to processes of scientific inquiry. The categories of content encompass "virtually all the content of school science instruction, both in traditional and modern courses, and reflects the divisions and subdivisions of the subject that are commonly accepted by contemporary science teachers and educators" (Klopfer, 1971, p. 580). Such a matrix implies scientific inquiry behaviors which cut across disciplines. Although this is antithetical to Schwab's analysis, such a matrix does point toward the relationship between various student behaviors and the content of the subject matter. This view is preferable to the dichotomous content vs. process arguments which raged during the 1960's. It should be noted, however, that this classification scheme still is not a detailed analysis. For example, a cell from the matrix is the Interpretation of Experimental Data and Observations (behavior) for Cell Structure and Function (content). A large quantity of knowledge remains unspecified within this category.

The researchers reviewed above have offered a variety of important perspectives. The work of Bruner and Schwab pointed to the importance of structure. Bruner argued from a psychological perspective. Schwab argued from an epistimologic vantage point. Both provided broad initial guidelines about the nature of the knowledge to be taught. Neither provided a framework for detailed analyses to be used in the design of specific instructional sequences.

Gagne points to the utility of detailed descriptions in instructional designs. However, the purely psychological perspectives do not develop important epistemologic considerations as indicated by both Schwab's and Bruner's positions. Klopfer also does not fully attend to the point that various disciplines are by their nature different and do not necessarily use common processes in their inquiries. However, he did illustrate that the behaviors or processes and content of science are not separable.

Within the literature epistemologic constraints have been discussed. These constraints now must be applied in the descriptions of subject matter. Greater detail from the analysis of what is to be taught must be available for purposes of instructional design.

Content-Task-Strategy Model

Smith has proposed a model for representing the knowledge to be taught. The model was used in this study as an analytic tool to generate the descriptions called for in the previous section. The analysis provided the relatively fine grain descriptions used in the design of the instructional sequence.

There are three components to the model; content, task and skills or strategies. Content analysis involved the identification and description of related concepts or sets of concepts. Task analysis results in descriptions of what information is initially given and ultimately required in the performance of the disciplinary tasks. Strategy analysis specifies at a psychological level how available information is processed in the performance of a specific task. Further description of these three components, the basic attending assumptions, and a brief elaboration are stated below. The final portion of the chapter describes the results of the analysis completed for this study. This example will elaborate the brief descriptions presented here.

Content Analysis

Assumptions:

(1) "Any discipline is built around a set of specialized conceptual systems.

(2) Many of the specialized conceptual systems of a discipline fall into a small number of categories, each of which share a common logical structure" (Smith, 1974, p. 2).

Description:

"Content analysis involves 1) the identification of the types of conceptual systems characteristic of a discipline or subdiscipline, 2) the formulation of a paradigm or analytic network which represents the structure of each type of system, and 3) the comprehensive identification

> and cataloging of the conceptual systems of a discipline according to the analytic network they exemplify" (Smith, 1974, p. 2).

The content analysis identifies sets of concepts which belong to a particular discipline. For geology such a set of concepts includes sandstone, shale, limestone, and siltstone. These concepts are similar in that each names a particular rock type. For this set of content-specific concepts (called "systemic" concepts) a single "analytic" concept is generated which must be of sufficient generality to represent the function of all similar concepts within the discipline. For example, the analytic concept "class name" can be applied to all specific concepts listed above. A complete but relatively small number of such analytic constructs when taken together, constitute an analytic network which specifies the logical relationships between specific or systemic concepts of the discipline.

Task Analysis

Assumptions:

1. "Most important competencies related to a discipline, at least from a general education point of view, can be presented as manipulations of conceptual systems."

2. "The level of mastery of a conceptual system may be adequately inferred from a defined set of observable behaviors" (Smith, 1974, p. 2).

Description:

> "Task analysis involves the identification of performance requirements relevant to a specific type of conceptual system. These requirements or tasks are described in terms of the corresponding analytic network (Smith, 1974, p. 3).

More specifically tasks are defined by presenting the analytic concepts which represent the given information and the information which is required as output by the person executing the task. A geologic task represented within this framework may be defined at the analytic level as:

Given:	one class name
Required:	statement of relevant variables

On the systemic level, the task could read:

Given:	the class name, sandstone
Required:	the variables, composition, texture, particle size

Smith suggests one of the ways of identifying tasks within a discipline is by having someone familiar with both the discipline and the task analysis model list tasks important to that discipline. This technique was utilized in the present study.

Strategy Analysis

Assumptions:

1. "Common information processing strategies are applicable to the utilization of conceptual systems sharing a common structure" (Smith, 1974, p. 2).

Description:

> "Skills analysis identifies alternative information processing strategies by which tasks can be performed. These are descriptions of behavior at the psychological level and provide the basis for planning and predicting transfer among tasks" (Smith, 1974, p. 3).

Skills or strategy analysis represents the psychological processes by which someone may complete a specified task. They are models of cognitive performance expressed as flow charts indicating the order or sequence in which various hypothesized processes are executed. Smith carefully describes the purpose of these models and the criterion for evaluation.

> ". . . the information processing strategies. . . are not intended as a description of how students actually do perform such tasks. The question of whether these strategies are valid or invalid as descriptions is not relevant. They are conceived as a description of one feasible and reasonably efficient way of performing such tasks, and as being trainable by some instructional procedures. The relevant criteria for evaluation ask: 1) Can instructional procedures be devised which result in acquisition of the intended strategies in a reasonable segment of instructional time? 2) Is the strategy effective, when carried out, in producing valuable behavior? and 3) Are the processing routines useful in predicting transfer relations among related learning events? Whether or not the intended strategy is a valid description of behavior is a relevant question only in relation to children who have received instruction designed to produce the strategy" (Smith, 1972, p. 75).

Each strategy consists of a sequence of primary, secondary and tertiary processes. "A processing step involving a primary process represents what for purposes of the analysis at least is to be considered a unitary skill, e.g., decoding a variable name" (Smith, 1972, p. 148).

Each process is defined in terms of the input and output of information and the operation which changes that information. Additional and more complex secondary and tertiary process are defined in terms of primary processes. Definitions of the primary processes and the detail of strategies for the geologic classification task are described later in the chapter.

Taken together the products of Content-Task-Strategy analysis represent the structure of a portion of a discipline. The description consists of related sets of concepts (conceptual systems), specified tasks to be performed with those concepts, and strategies which model at a psychological level how the task can be performed.

Psychological Views of Learning and Transfer

Shulman and Tamir have pointed out that within science education one of the major issues has focused on ". . . what is most learnable under given conditions, (and) what is most readily retained and transferred to new situations. . ." (1973, p. 1105). A number of psychological perspectives were brought to bear on this issue, and science education programs developed on the basis of those perspectives. The major contributors were Bruner, Gagne, and Ausubel.

Bruner viewed learning and transfer as dependent upon the structures of the subject to be learned. He argued for learning the structure in the sense that "to learn structure, in short, means to learn how things are related" (1963, p. 7). Bruner's particular interest was in what he called non-specific transfer, or the transfer of principles and attitudes. This type of transfer, in contrast to transfer of specific skills, is viewed as the most important way in which learning serves the future.

> "In essence, it (non-specific transfer) consists of learning initially not a skill, but a general idea, which can be used as a basis for recognizing subsequent problems as special cases of the idea originally mastered.
>
> "The continuity of learning that is produced by the transfer of principles, is dependent upon mastery of the structure of the subject matter. That is to say, in order for a person to be able to recognize the

> applicability or inapplicability of an idea to a new situation and to broaden his learning thereby, he must have clearly in mind the general nature of the phenomenon with which he is dealing. The more fundamental or basic is the idea he has learned, almost by definition, the greater will be its breadth of applicability to new problems" (1963, p. 17).

Also important to Bruner's conception of the transfer phenomena was the notion of strategies or heuristics for inquiry and the potentially broad applicability of general strategies. In fact, Bruner argues that through extensive experience in discovery or problem solving situations one learns "the working heuristic of discovery. . . that serves for any kind of task one may encounter or almost any kind of task" (Bruner, 1961, p. 30).

While Bruner argued that the general relationships were most important for learning and transfer, Gagne was concerned with the learning detailed sequences of prerequisite capabilities. These capabilities are considered internal to the learner and are described in terms of the observable behaviors of the learner. Complex intellectual skills are learned most easily when constructed from simpler skills, hierarchically organized. Transfer to more complex tasks is dependent upon the learning of the simpler prerequisite components. This type of transfer Gagne labels vertical transfer. It "is observed when a capability to be learned is acquired more rapidly when it has been preceded by previous learning of subordinate capabilities" (1970, p. 337).

In contrast Gagne describes lateral transfer. This is concerned with the way previous learning can be used in new situations of approximately the same complexity. Gagne is less specific concerning mechanisms for lateral transfer than those for vertical transfer. He proposes that the lateral transfer of a learned capability is enhanced by practice in a wide variety of situations, but he leaves open the question of whether the ability to transfer capabilities broadly is largely innate or learned.

Ausubel (1965) contends that what is most easily learned is knowledge of the subject matter and that this is what transfers. The knowledge is most easily learned if there is available in the existing cognitive structure concepts which can "subsume" the newly introduced material, thus providing a stable organizational framework to which the new knowledge can be anchored. More specifically, learning is dependent upon the "organizational properties of the learner's subject matter knowledge (such as clarity, stability, generalizability, inclusiveness, cohesiveness, and discriminability, not (the) degree of similarity between stimuli and responses in the two learning tasks" (1965, p. 108). In this point Ausubel takes issue with Gagne's common elements view. He furthermore disagrees with Bruner's view that non-specific transfer is limited to problem solving situations where principles can be used to recognize a particular problem as a special case of more inclusive structures of the subject matter. Ausubel clearly points out that reception learning of new content is affected either positively and/or negatively by previous experience and therefore is also a transfer phenomena of major importance.

In more recent work, Smith (1972), has presented a view of learning and transfer which emphasizes shared concept, task, and skills or strategy components. In particular, he has emphasized the role of cognitive strategies.

He has defined lateral and vertical transfer as related to the Content-Task matrix shown in Figure 1. The various possible contents shown across the top of the diagram represent related conceptual networks which function in similar ways within the discipline. The conceptual networks are considered structurally similar. Vertically the matrix shows a set of related tasks described in terms of analytic constructs. These task descriptions reflect the nature of the conceptual systems and are statements of what is done with the related sets concepts. Tasks can be sequenced on the basis of shared strategy components where the strategies of simpler tasks serve as subroutines for the more complex tasks. Lateral transfer refers to the performance of the same task across different conceptual systems. Vertical transfer refers to performance on a sequence of tasks within the same conceptual system.

Smith argues that cognitive strategies may serve as a mechanism for learning and transfer. With respect to lateral transfer, Smith asserts that once a strategy for performing a task has been learned with one set of concepts, the learning of that task using a different conceptual system will be mediated by the availability of the strategy. The strategy serves as a stable organizing sequence of information processes which coordinate the use of parallel concepts. Whereas lateral transfer is dependent upon the use of the same strategy across various contents, vertical transfer occurs within the same set of concepts across different tasks. The facilitative effect of the strategy in this case is dependent upon the compatability of the

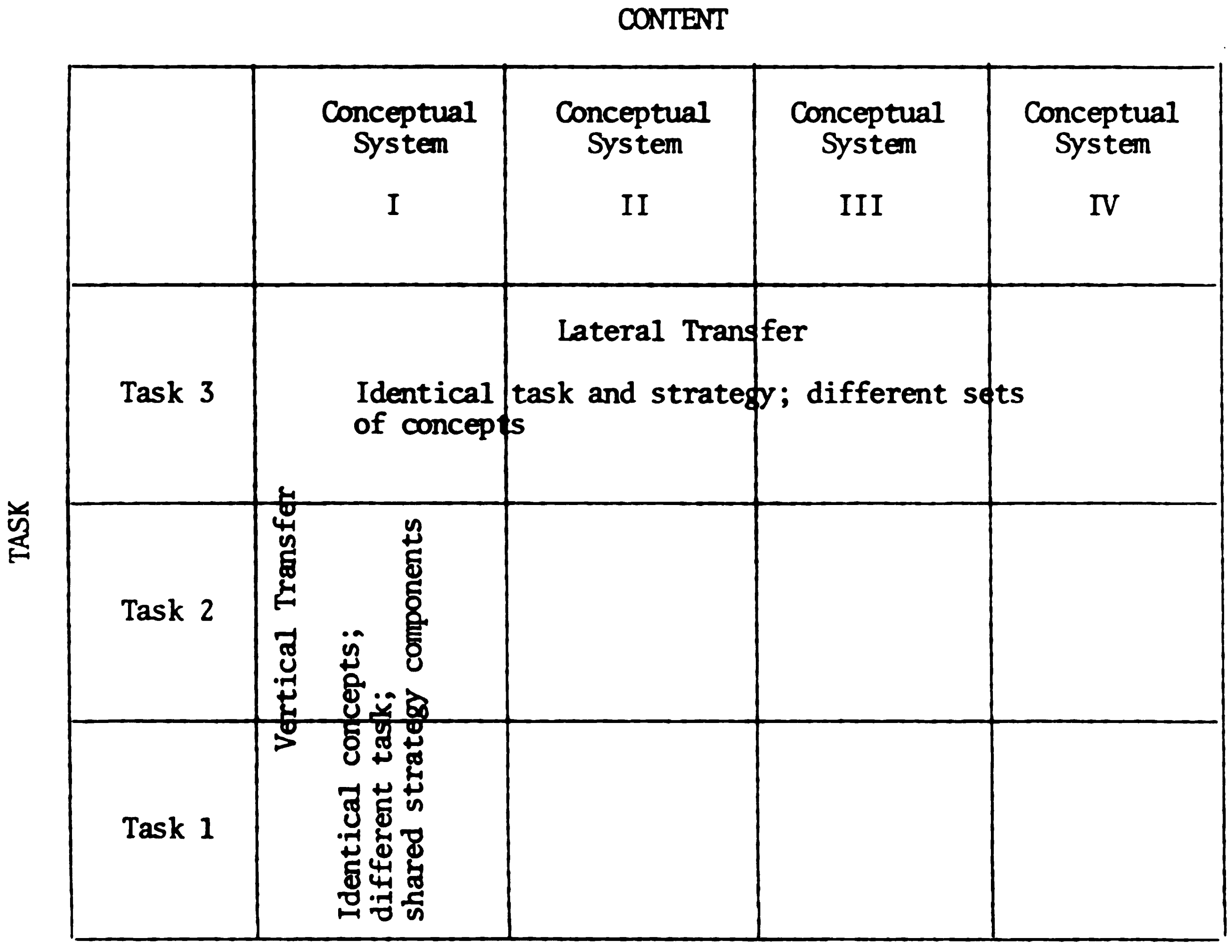


Figure 1. Task-Content Matrix

strategies for less complex preceding tasks. "Once a strategy for a task has acquired some degree of stability, it can function as a subroutine in a larger strategy" (Smith, 1974, p. 12). If learning tasks within an instructional sequence have been arranged with due consideration for the common strategy components, learning and transfer within the sequence should be enhanced. It is this facilitative effect of cognitive strategies in a vertical task sequence that is the particular interest of this study.

Information Processing Psychology

Smith's work is largely dependent on the broader field of information processing psychology. By reviewing the work of Newell and Simon (1969, 1971, 1972), the description of the role of strategies in task performance can become more complete. In addition, a more complete picture of the human information processor is available for use in the design of instruction. The review is divided into three sections: 1) the characteristics of the human information processing system, 2) the task environment, and 3) the problem space.

The Human Information Processing System

The human information processor is dependent upon the manipulation of symbols. Those symbols designate the information available in the external environment and information available within the processor. One symbol can be a complex structure of other symbols organized by the use of simple logical relationships.

Upon receiving information from the external environment, it can be encoded as symbols and stored for future use. Symbols often refer to chunks of information, a chunk being the largest recognizable stimulus configuration. These chunks are learned patterns of information. Symbols may also reference programs or strategies for processing information and conceptual knowledge stored in memory. One other important type of symbol is the goal which controls the behavior of the information processor. The goal of obtaining a problem solution in a given situation is ultimately a test which when executed results in a decision as to whether or not the problem has been solved. If the solution is not met, the next operations performed are responses to the existing differences between the present state of knowledge and the goal or final desired state.

There are three central components to the information system. The first is the processor which consists of elementary information processes, a short term memory (STM), and an interpreter. The second is a long-term memory (LTM) and the third an external memory (EM). Taken in total, the system processes the information within the STM which has been taken from either of the two memories. The processing is serial, that is, only one of the elementary processes can be executed at a time.

Within the processor, elementary information processes (eip's) operate on symbols. The eip's are a limited set of operations which can compare, designate, or alter an input symbol in a specified manner. The processes are simple in that only one or two symbols at a time are used. The behavior of the information processor is constructed from organized sequences of these processes. These sequences of information processes, called strategies by Smith (1974) are central to this study. Strategies can be constructed from the elementary processes within the attempt to solve a given problem or exist as symbol structures in long term memory to be recalled into STM and executed.

Short term memory is the component which holds the inputs and outputs of the elementary processes. Newell and Simon describe the character of STM as follows:

> ". . . STM holds about five to seven symbols, but only about two can be retained for one task while another unrelated task is being performed. All the symbols in STM are available to the processes, i.e., . . . there is no accessing or search of STM" (1972, p. 808).

The character of STM is particularly important as it is a major restraint on the capabilities of people to process information.

The interpreter determines the sequence of the elementary processes to executed. It is described as a program or strategy which controls the cognitive action of the problem solver. This program can be constructed in STM strictly from elementary processes or simply be able to interpret other programs called into short term memory. The interpreter integrates the behavior of the information processor by organizing the sequence in which available symbols are processed.

The second major component is long term memory (LTM). In this memory a virtually unlimited number of symbols or symbol structures can be stored. These symbols are organized as lists of lists. The organization of lists are maintained by various logical relations. The entering of new chunks of information into long term memory is a relatively slow process taking from 5K to 10K seconds for meaningful chunks (Simon, 1969, p. 39).

In addition to STM and LTM, a third memory, the external memory (EM) is associated with the processing system. This is "immediately available visual field" (Newell and Simon, 1972, p. 809). Information can be stored in and retreived from the external memory.

Task Environment

The processing system just described is relatively simple. Its capabilities are set by a relatively few limiting factors such as the 5-7 chunk limit of STM and the serial nature of the processing. The adaptive nature of the system reflects the ability to change, i.e., to alter its behavior in response to the task which it is required to perform. It is the information and structure of the task which to a great extent demands or necessitates certain behaviors. Different tasks result in different behaviors from the same human information processing system.

Newell and Simon use the term "task environment" to refer "to an environment coupled with a goal, problem, or task. . ." (1972, p. 55). The task environment consists of (1) the information immediately and externally available to the problem solver and (2) invariant structures which limit the range of possible behaviors. There are certain features of the environment which form the relevant structure of the environment and demand certain behaviors in the successful performance of a task. A demand of the task environment is "a constraint on the behavior of the problem solver that must be satisfied in order that the goal be maintained" (Newell and Simon, 1972, p. 79). It should be emphasized that the goal, or required outcome of the task determines what are and are not demands of the environment. A change in the specified goal would make certain features of the environment demanding and others irrelevant.

Thus, to understand the performance of an individual completing a given task requires careful and detailed description of the task environment. Even though as noted by Newell and Simon, the task environment cannot be completely objectively described, the analysis of that environment must precede the investigation of a problem solver's behavior. The major features are those available to any individual confronting the task. This includes the information given in the initial presentation of the task and the logical relationships which place demands on performance. The features should be inherent in the task, not related to the nature of the problem solver.

Problem Space

The problem space is a mental construction of the problem solver. It contains information from the task environment and long term memory, and a goal which indicates when the task has been completed.

The relationship between the task environment and problem space is important to consider. The structure of the task environment limits the range of possible information to be included in the problem space. This does not imply that the adopted problem space will be an exact representation of the task environment. In fact, the problem space is an abstraction which will contain only a small portion of the available information. This may or may not be sufficient to solve the problem at hand. However, it is clear that the better the problem space reflects the structure of the task environment, the more likely the individual will correctly solve the problem. Newell and Simon describe the relationship as follows:

> "A problem space may contain more or less structure than the environment it represents. If it contains more. . . some of this structure will be spurious. It will be at best useless, and possibly harmful to the problem solving process. If the problem space contains less structure than the environment, it may not permit maximum use of the structural information that is potentially available" (1972, p. 825).

The above should not imply that the only information in the problem space is from the external environment. The individual includes in his representation of the task knowledge recalled from long term memory. The total construction of the problem space can be considered as the result of an interaction between the previous learning internal to the problem solver and the external task environment at hand.

Instructional Design

Gagne (1970), Bruner (1971), Scandura (1973), Merrill and Boutwell (1973) and others have developed sets of dependent and independent variables which should be considered in the design of instruction. Some variables have pertained to the learner, others to the content of instruction, and still others to the type or style of the instructional presentation. Each viewpoint contains implicit assumptions about the manner in which these variables should be used in the process of designing instruction. The following reviews the work of Simon to explain the design process used in this study.

Simon considers design as the development of courses of action which will change existing situations into preferred ones.

An artifact is considered the interface between the outer environment of the world in which it exists and its own inner environment. Both the outer and inner environments can be described in terms of the properties and laws which describe the interactions therein. The natural sciences often provide these descriptions. Most importantly, an artifact is designed to meet certain goals. An effective and efficient design is one which constructs the artifact so that the inner environment can respond to the outer environment appropriately. It would seem that construction of such designs could be facilitated by detailed descriptions of the major features of the inner and outer environments.

Simon also argues that the human being is essentially an artificial system in that it can adapt to the demands of the outer environment. There is:

> ". . . evidence that there are only a few 'intrinsic' characteristics of the inner environment of thinking man that limit the adaptation of his thought to the shape of the problem environment. All else in his thinking and problem-solving behavior is artificial--is learned and is subject to improvement through the invention of improved design" (Simon, 1969, p. 26).

The last sentence is the key to the design of instructional sequence in this study. As a result of having completed the specified instructional sequence the individual will have learned information necessary to the performance of the specified tasks. That is, the inner environment of the learner will be altered so that it is appropriate to the demands of the outer environment or nature of the task to be performed. The extent to which this is the result of instruction should be reflected in the performance of the individuals being taught.

The design of instruction, then, requires:

1) A description of the outer environment, information to which the learner has explicit reference in performing a task.

2) A description of the general characteristics of inner environment of the problem solver.

Instruction is viewed as the course of action taken to make available conceptual knowledge and strategies for the construction of an appropriate problem space.

How, then, can the necessary descriptions be gained so that the instruction can be designed? As the content of instruction is to be taken from a discipline, the delineation of the structures of that discipline can provide the descriptions of the task environment and a model of an appropriate inner environment or problem space. Smith's model of content-task-strategy analysis described earlier will be used to provide these descriptions. These descriptions cannot be exact replicas of the real world or the world as it would be viewed by any given problem solver. What is described are the major features used by those working in the discipline to classify igneous rock samples. These include the concept labels, logical relationships, and a goal or required outcome of the task environment, and the concepts and strategies of a model problem space. Smith's model was chosen as it provides an analytical framework which facilitates obtaining these descriptions and maintains the relationships between the various structures of the discipline.

Given these descriptions a sequence of instruction can then be designed by considering the general nature of the human information processor. The description includes the limits of short term memory, the time required to store "chunks" of information, and the serial nature of the processor. Each of these point to important considerations in design of instructional episodes.

CONTENT-TASK-STRATEGY ANALYSIS OF THE CLASSIFICATION OF IGNEOUS ROCKS

Within this section the analysis of igneous rock classification is presented in three parts. The first is the content analysis which identifies the set of related concepts which the discipline utilizes to classify the rock samples. The relationship of the concepts to each other is made explicit by use of the class member analytic network by Smith. This set of concepts will also serve in the description of the task environment and model problem space.

Secondly, a task analysis describes in analytic terms the task which the students must learn to perform when classifying igneous rocks. The task description is composed of the information initially given and the required outcome or goal. This further describes the task environment and problem space.

The strategy or skills analysis results in a model cognitive strategy for task performance. This describes one way the task can be performed. An appropriate strategy is to be considered a potentially important problem space component.

The final section presents the design of the instructional sequence used to teach students to classify the igneous rock samples. This includes specification of pre-task instructions, the precursor tasks, and strategies for performing those tasks which were developed to facilitate learning of the final task.

Geologic Classification

Geology is the science of the earth, a major subdivision of which is physical geology. This portion of the discipline addresses, in part "the nature and properties of the materials composing the earth. . ." (Leet and Judson, 1965, p. 1). Central to these inquiries is the concept rock which could be considered the central unit of study for physical geologists.

The classification of various rock types serves to organize the descriptions of the phenomena under investigation so that the scientific community can share information gleaned from their inquiries in a systematic and understandable manner. Furthermore, the field classification of rock samples with which this study is concerned is closely related to the theoretical issues of the discipline. Field classification implies the use of variables which are visible in hand samples or rock outcrop as the basis of classification. Additional, more complex classification schemes are used as the observational technique becomes more sophisticated in the laboratory.

Content Analysis of Geologic Classification

The content analysis is to identify related sets of concepts and the relationships between those concepts. The meaning of any one concept is dependent on others with which it is systematically associated. In association with the concept rock are terms such as igneous, metamorphic, and sedimentary. This study is confined to the subsets of igneous rocks.

In the analysis of concepts attendant to the classification of igneous rocks, the class-member analytic network described by Smith provides the organizational framework. In addition, the analytic constructs "elements" and "comparative" are taken from another analytic network, the Variable-Value Network. They are included as they are used in the definitions of the class-member constructs. This is possible as the two networks are logically related. The following analytic terms describe the character of specific concepts:

1. "element - the entities (objects, events, systems constructs, etc.) which are being studies" (Smith, 1972, p. 89).

2. "comparative - term representing the relation between the values of a single variable (or descriptions on a set of variables) which characterize two or more elements (or an element at different times)" (Smith, 1972, p. 89). This implies one value is greater than, equal to, or less than another value for the same variable.

"Definition of the class-member analytic Network:

3. class - a designated set of elements

4. class member - an element of a class

5. class rule - a decision by which it may be determined whether or not an element is a member of a class

6. class name - a name applied to an element as a result of its membership in a class

7. defining value - a value employed in a class rule

8. defining value name* - name which describes a particular defining value or the set of defining values included by a pair of defining values as specified by a class rule

9. relevant variable - a variable whose values are employed in the rule for a class or a set of classes

10. partition - a set of mutually exclusive classes, i.e., superordinate class

11. partition name - a term or phase referring to a specific partition" (Smith, 1972, p. 119).

Using these analytic concepts as guidelines, the following specific geologic concepts are identified as related to the classification of igneous rocks (Table 1). The symbols following the examples of specific geologic (i.e., systemic) concepts correspond to those symbols used in Figures 2 and 3. These figures illustrate the relationships between the various concepts. They are constructed at the analytic level to illustrate their generality of their use.

The most general organization of these analytic concepts into a classificatory scheme is shown in Figure 2. Relevant variables are used to define each class. These may or may not be the same. The defining values indicate the limits between which the value for a

*Note: The defining value name is added to Smith's original network as necessary to fully describe the concepts related to igneous classification.

Table 1. Analytic and Systemic Concepts for Igneous Rock Classification

Analytic Concept	Systemic Concepts (Exemplars)
element	any rock sample (e)
class members	individual rock samples belonging to a class
class	a set of rock samples identified by the class names stated below
class names	granite (C_1), diorite (C_2), gabbro (C_c) rhyolite (C_4), andesite (C_5), basalt (C_6), glass (C_7), obsidian (C_9)
relevant variables	grain size (A), amount of light grains (B)
defining values	a_1, a_2 for the variable grain size; b_1, b_2 for the variable amount of light grains (These values are usually specified by standard examples, not quantitatively.)
comparative	the value for a rock sample (e) is greater than (>), equal to (=), or less than (<) the value for a particular standard
class rule	For a given element (rock sample e), the value 'a' for the variable grain size (A), and the value 'b' for the variable amount of light grains (B) in conjunction with the set of class rules below specify class membership: If $a \geq a_1$, and $b \geq b_1$, then $e \varepsilon C_1$. If $a \geq a_1$, and $b_2 \leq b < b_1$, then $e \varepsilon C_2$. If $a \geq a_1$, and $b < b_2$, then $e \varepsilon C_3$. If $a_2 \leq a < a_1$, and $b \geq b_1$, then $e \varepsilon C_4$. If $a_2 \leq a < a_1$, and $b \leq b < b_1$, then $e \varepsilon C_5$. If $a_2 \leq a < a_1$, and $b < b_2$, then $e \varepsilon C_6$.

Table 1. (Continued)

Analytic Concept	Systemic Concepts (Exemplars)
	If $a < a_2$, and $b \leq b_1$, then $e \in C_7$. If $a < a_2$, and $b \leq b < b_1$, then $e \in C_8$. Of $a < a_2$, and $b < b_2$, then $e \in C_9$.
defining value name	$a \geq a_1$, large grains (VN_1); $a_2 \leq a_1$, small grains (VN_2); $a < a_2$, glassy (VN_3); $b \geq b_1$, mostly light grains (VN_4); $b_2 \leq b \leq b_1$, about 1/2 light grains (VN_5); $b < b_2$, mostly dark grains (VN_6).
partition	a superordinate class, igneous rocks, subdivided into the nine subordinate classes listed above.
partition name	igneous rock types

given element must fall if it is to be considered for class membership. In this scheme classification is dependent on meeting this condition for two relevant variables per class. Any element meeting both conditions is a member of the designated class.

In the classification of igneous rocks the variables which are used to define each class are the same, but the defining values are different. Utilizing the two appropriate defining values for each variable, the diagram in Figure 2 collapses to the classification scheme shown in Figure 3.

Partition Name

Class Name

Class Name

Relevant Variable A

Relevant Variable B

a_1 Defining values a_2

b_1

Defining Values

b_2

Class members

elements

e_1 - e_x

Class Name

Relevant Variable C

Relevant Variable D

C_1 Defining Values C_2

d_1

Defining Values

d_2

Class members

elements

e_1 - e_x

Figure 2. Generalized Classification Scheme (Analytic Level)

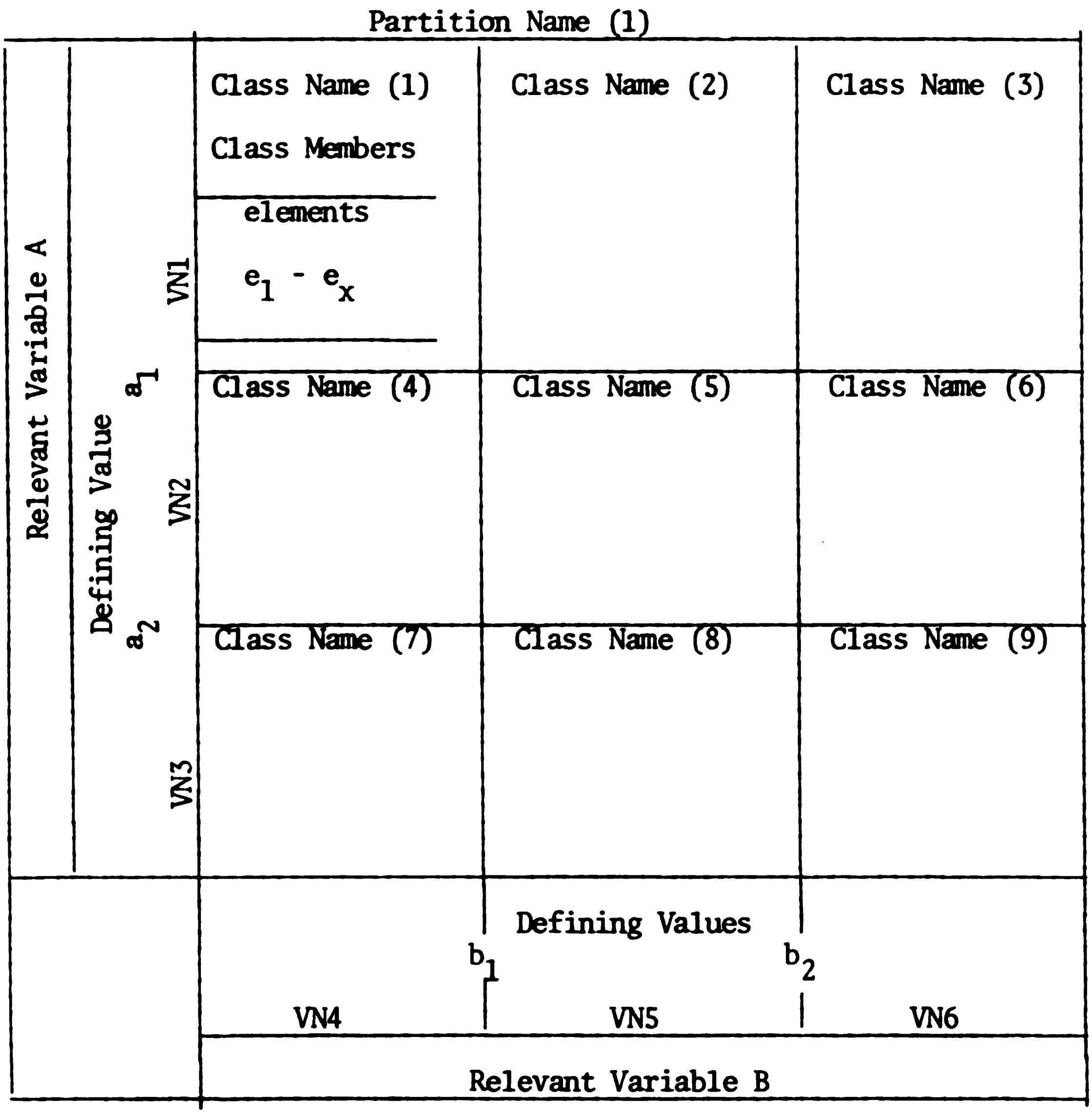


Figure 3. Specific Classification Scheme for Igneous Rocks (1)

The final figure represents the organization of the concepts used in the classification of igneous rocks. When the analytic concepts are replaced by the appropriate discipline specific concepts the classification scheme used in instructing students is generated.

The structure of the task environment is set by the arrangement of these concepts (see Figure 4). The absence of any component would meaningless. For example, to classify non-existant elements by unspecified variables without benefit of defining values or a consistent class rule would not be possible. However, all concept labels displayed and available for use by any individual are considered as part of the task environment. This follows the suggestion of Newell and Simon. It is consistent with their view that this task is isomorphic with a considerable number of other classification tasks. That is, the analytic constructs remain invariant, even though the discipline specific constructs may change.

Task Analysis

The task environment has not been described completely as yet. What has been described are the concepts of the discipline used in the task. However, "The term task environment refers to an environment coupled with a goal, problem or task. It is the task that defines a point of view about an environment, and that in fact allows an environment to be delimited" (Newell and Simon, 1972, p. 55). To describe a task or goal implies that certain information is given to the individual and that additional information or output will be required. This states what the individual is to do with the information explicitly given.

Generally stated, in geologic classification individuals are required to identify the class to which a given rock belongs using the information available in a given classification scheme. Specifically, what is given and required are stated below at two levels. The first, or analytic level, describes the invariant structural features.

The second describes the discipline specific concepts which the individuals actually use in performing the task.

Double Variable Classification Task Description

Analytic Level Task		Systemic (Concept) Level Exemplars	
Given:	an element; two relevent variables; two defining values for each variable; six defining value names; a set of class rules.	Given:	an igneous rock sample; grain size, amount of light colored grains; two standards representing the defining values for each variable; large grains, small grains, about half light grains, mostly dark grains.
Required:	the element placed in the class of which it is a member.	Required:	the rock sample placed in the class to which it belongs.

Two additional comments are necessary. The task as specified above, does not require the use of the class names. The reading and output of the class names would usually follow the placement of the sample. However, the students were unfamiliar with those names. The reading and pronunciation would have been an additional instructional problem and was assumed not critical to the central problem of correct sample placement. Secondly, the defining values were specified by rock samples which served as standards placed on the classification board used for instruction. The values of these variables are not usually described quantitatively, yet, the task requires they be represented clearly. Thus, standard samples exhibiting the necessary values were utilized.

Skills or Strategy Analysis of Geologic Classification

The purpose of the strategy analysis was to develop a model of the information processing steps which would be sufficient to complete the specified task. The inputs and outputs are information described in terms of concepts from the discipline. The strategy is to become a program in long term memory. It was expected the individual can call upon the program for inclusion in the problem space he constructs to meet the demands of any of a set of structurally similar tasks.

The source of this analysis is not what an experienced geologist would do, as the information available in LTM would be very different from that of a novice. The result would be quite a different strategy. In fact, the classification task would for the most part be a relatively simple matter of the rock sample being an immediately recognizable chunk of information. However, in a problematic sample the geologist may make a comparison to a mental model of standard or type samples to arrive at the classification and/or recall specific defining values for certain classes. This comparison-to-standard was the basis of the strategy students were taught.

The particular strategy utilized in this study was developed from three considerations: 1) a logical analysis of how the available information could be used by a novice, 2) the possibility of geologists using a memory of standard samples, and 3) a pilot study of teaching alternative strategies to novices to assess the sufficiency and feasibility of the strategy model.

The following describes the strategy for performing the classification task. Figure 4 shows the exact classification scheme used by the students and may be helpful in understanding the description. Following an overview of the strategy the definitions of the specific information processes and a flow chart model of the strategy are presented.

The strategy for the Double Variable Classification Task begins with the selection of one of the relevant variables, grain size. The student compares the sample to the larger value standard for that variable. The sample must be placed in close proximity to the standard. The decision is whether the sample has larger, equal size, or smaller grains than the standard. If the grains are larger or of equal size, the sample is designated as belonging in the row preceding the standard. If the grains are smaller, the next standard is used in the same way. To facilitate encoding of the decision the students verbalize the label for the selected row. After the row has been selected, the remaining variable, amount of light colored grains, is selected and the above process is repeated for that sample until the correct column is located. In this way, by making a series of comparisons to standard, the class in which each sample is a member can be located.

To precisely describe the cognitive strategy from which the description is taken a flow chart presentation is utilized. Several symbols used in the flow charts are defined below in Figure 5.

The unitary or primary processes from which the strategy is constructed are characterized in Table 2. These abbreviated descriptions

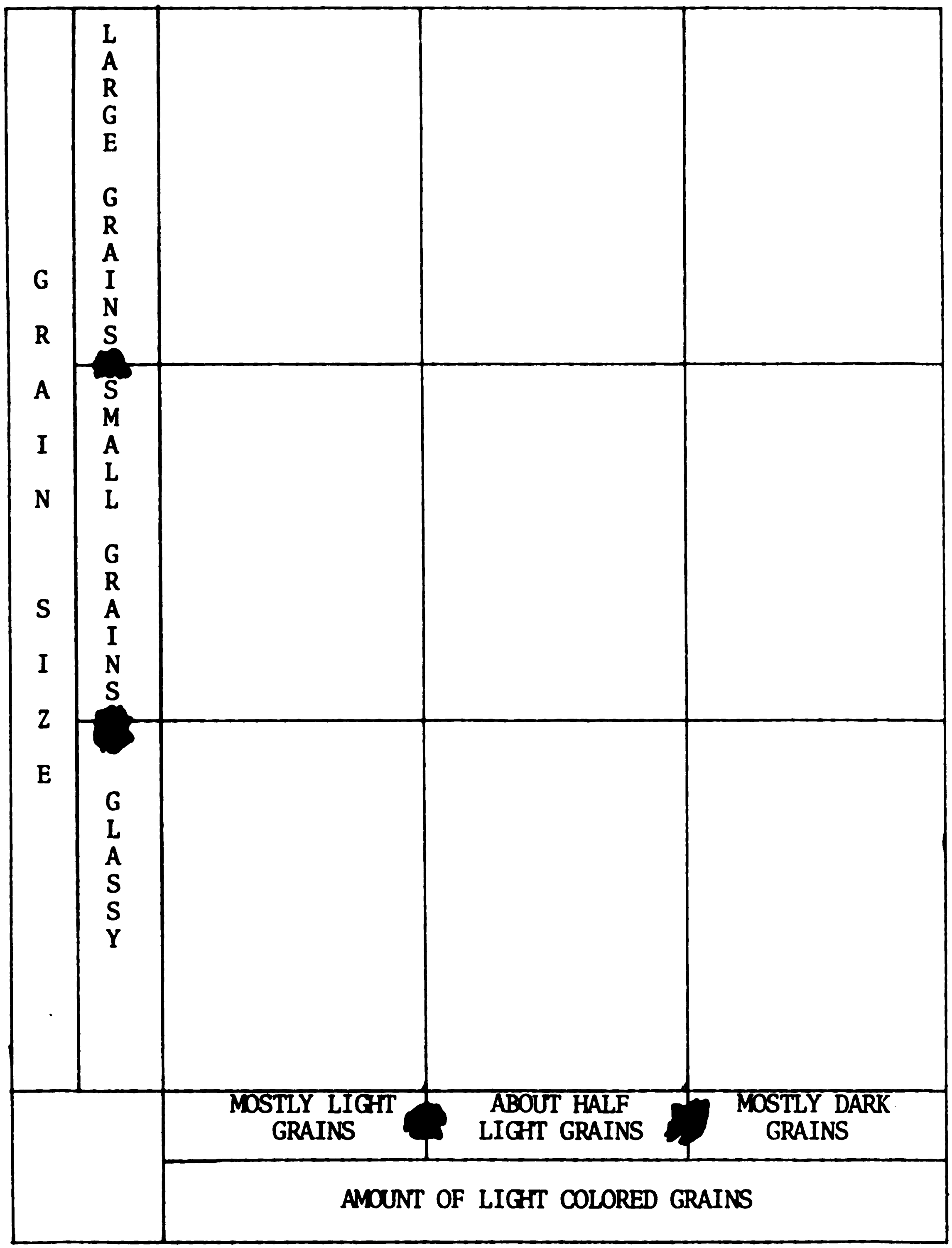


Figure 4. Double Variable Classification Chart

s - rock sample

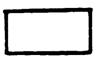
S - standard sample

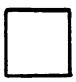
v - value of a variable for a particular sample

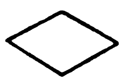
V - defining value for a standard

NV - value name

RV - relevant variable

 primary information process

 secondary or tertiary information process

 indicate a decision is required

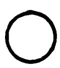
 indicates end of strategy

Figure 5. Flow Chart Symbols

are abstracted or taken directly from the references cites. LOCATE is the only process defined originally within the present study. The exact definitions of these processes are given in Appendix A.

The following two flow charts define secondary and tertiary processes necessary to the strategy model for the geologic classification task.

The first flow chart (Figure 6) describes a secondary process called COMPARISON first described by Smith, McClain, and Kuchenbecker.

Table 2. Description of Primary Information Processes

ACT	the process of acting on an object to obtain a particular kind of input (e.g., color or temperature information). The process requires the retrieval of an appropriate observation action (Smith, 1972, p. 153).
CHOOSE 1	operates on a set of stimulus objects. A choice of one object is made on the basis of some salient criterion such as a particular feature of position (Padilla, 1975, p. 204).
COMPARE	determines the comparability of two encoded units of information, e.g., the texture of two objects. The process determines if the objects are the same or different (Smith, 1972, p. 155).
DECODE	this process functions to gain access to the network of stored concepts. The network is entered by way of verbal label for one of the consistent concepts (Smith, 1972, p. 150).
ENCODE	categorizes sensory non-verbal information which has been attended to in terms of previous experience or creates a new category (Smith, 1972, p. 154).
LOCATE	involves the search for a position logically or spatially related to a particular source of information in the environment. The input to the process may be another position, object, or verbal label.
ORDER	attends to and assesses the magnitudes of two different encoded units of information and orders them from lesser to greater (Smith, 1972, p. 156).
PLACE	the spatial placement of an element to indicate its membership in a set (Smith, 1972, p. 155).
REPORT	allows verbal responses to be made. The output is a verbal label. The input is a concept (Smith, 1972, p. 157).

Table 2 (Cont'd.)

SCAN	represents a rather cursory, largely visual exploration of the stimulus field to locate salient and/or relevant features (Smith, 1972, p. 152).
SELECT	sort relevant information from irrelevant. It filters out almost all information except for that related to the variable or variables of interest (Smith, 1972, p. 153).

> "This is a secondary process which takes as input a variable concept (i.e., the node activated by decoding of variable name or an appropriate retrieval process) and an ordered pair of elements. It compares the elements on the given variable and outputs a comparative concept applicable to the ordered pair of elements. Thus, the COMPARISON process does not produce a verbal report although it makes such a report immediately possible. Alternative steps might be carried out next instead. The identities of the elements and the comparison variable are maintained. (Figure 6) indicates a parallel execution of processing steps. This indicates the desirability of near simultaneous observation of the two elements. "Parallel processing" in the technical psychological sense is not implied. Furthermore, feedback from the selecting and encoding steps to the ACT step undoubtedly occurs creating an active subsystem. Such feedback systems are very common, but to avoid excessive complexity, are not always diagrammed." (Smith, 1972, p. 161).

The second flow chart (Figure 7) defines a tertiary process CLASSIFY defined for the present work. This process encorporates the COMPARISON secondary process as a critical subroutine. The CLASSIFY process takes as input a variable name, an element to be classified, and some number of elements which represent the defining values of a number of classes. Also given is a class rule which defines a class in which a sample should be placed. The decision rule is implicit in the CLASSIFY process.

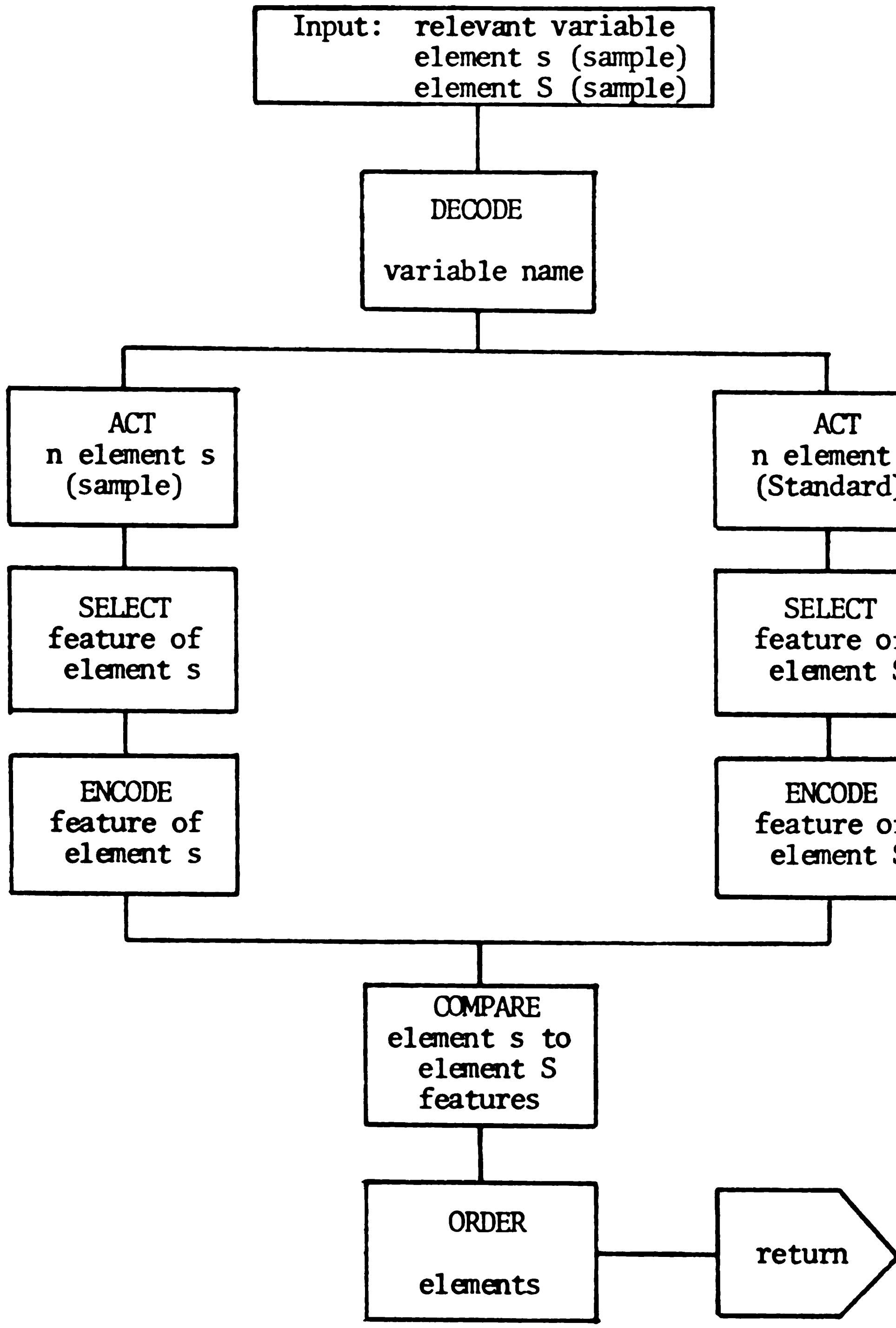


Figure 6. Comparison Secondary Process

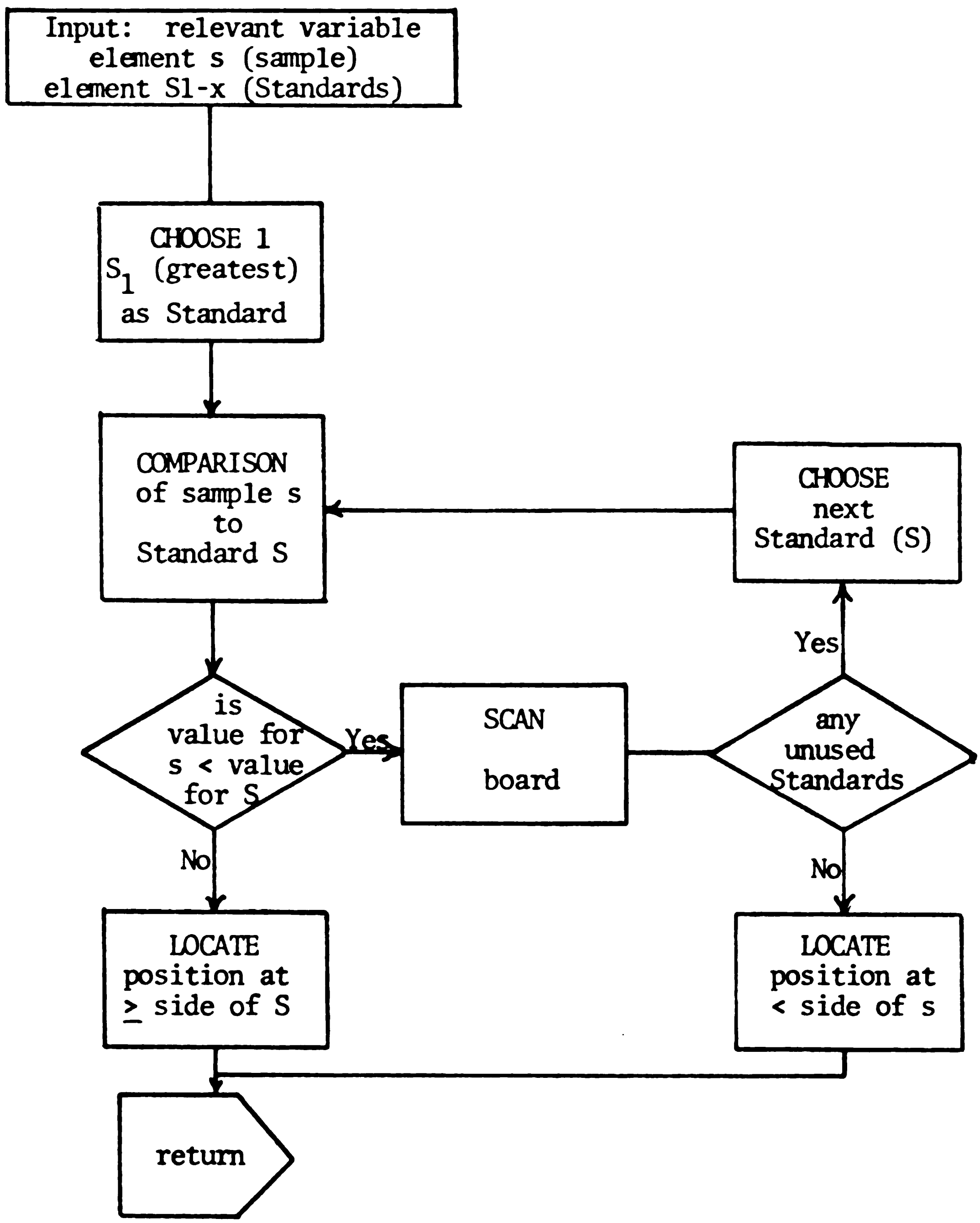


Figure 7. Classify Tertiary Process

The tertiary process ends where the class to which the element belongs has been unequivocally determined for a single variable. This occures when the appropriate position has been located because (1) the value for the sample is greater than or equal to the value of the standard or (2) no standards which define additional classes remain unused. Additional processing steps resulting in specified outputs may follow.

The next flow chart (Figure 8) specifies the entire information processing routine for the Double Variable Classification Task utilizing the CLASSIFY tertiary process.

Reviewing briefly the task was described as follows:

Double Variable Classification Task Description

Analytic Level Task	Systemic (Concept) Level Exemplars
Given: an element; two relevant variables; two defining values for each variable; sex defining value names; a set of of class rules.	Given: an igneous rock sample; grain size, amount of light colored grains; two standards representing the defining values for each variable; large grains, small grains, about half light grains, mostly dark grains; (See page 56)
Required: The element placed in the class of which it is a member.	Required: The rock sample placed in the class to which it belongs.

The model includes the processes which result in the necessary decisions and the outputs required by the task. In addition, verbal output is included in the strategy which are not required by the task. These are the verbal responses indicating the value name which corresponds to the classification decision made on each variable. Pilot study indicated that students could often not recall the

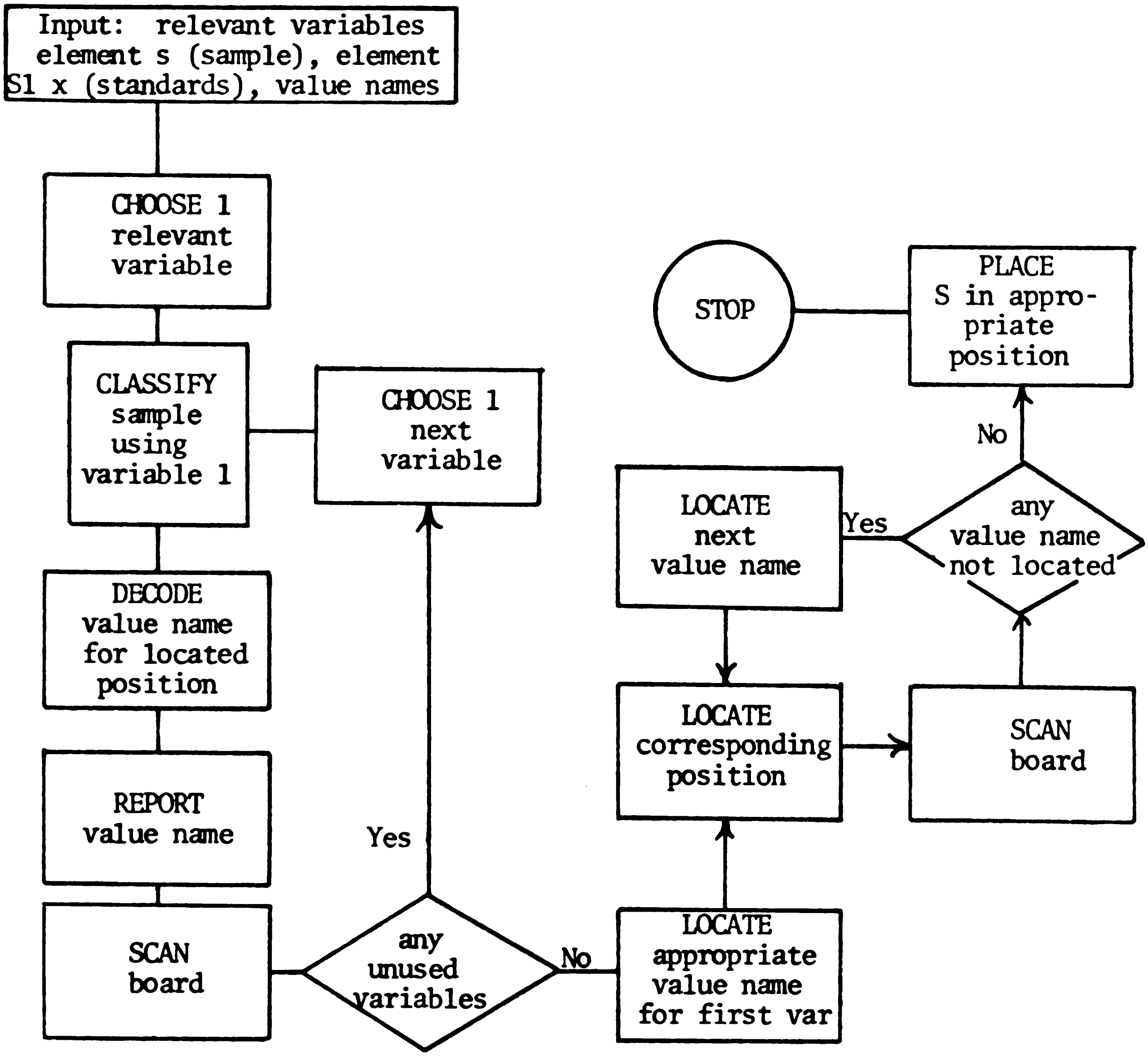


Figure 8. Strategy for Double Variable Classification Task

column or row in which the sample was to be placed. The required verbal output facilitated the location of that position when it was needed near the completion of the routine.

Design of Precursor Tasks and Strategies

The process of designing an instructional sequence which would result in students being able to classify igneous rock samples attempted to follow Simon's view of design. As stated before, design is considered the construction of an artifact with an environment appropriate to a particular outer environment. In this case the instruction is to result in the formation of an inner environment of the problem solver which is appropriate for accomplishing a particular task. The inner environment must contain information which enables the individual to construct a problem space in which a specified goal can be efficiently and accurately attained. The problem space must conform to the demands of the task environment in which the goal is imbedded. The problem space should be such that the information available in that external environment and stored in long term memory are effectively integrated in the performance of the task.

The necessity of designing the task sequence is dependent on a number of factors. First, it was expected that the task environment was too complex for students to be able to perform the task without instruction. Too many chunks of unfamiliar information would have to be coordinated for successful performance. Secondly, it is based on the assumption that the strategy just described was too long and complex to be learned and applied in an unfamiliar task environment during a single session. These assumptions would be expected, considering the slow encoding times of recognizable (let alone unfamiliar) chunks of information. The preliminary pilot study clearly confirmed these expectations.

In the light of the information processing literature, an attempt was made to reduce the complexity of the final task to identify precursor tasks which would form the instructional sequence. This was first done by a logical or rational analysis of the final task. The task was analyzed to identify additional tasks which were less complex in terms of the number of the specified inputs and outputs. The percursor tasks were also selected so that the logic of any preliminary task was consistent with the logic of the following task. This necessitated consideration of the class rules as identified during the context analysis. This analysis reduced the number of chunks of information to be learned in any single instructional session.

Following Smith's argument for expecting subroutines of a complex strategy to serve as mechanisms of learning and transfer, the strategy of the final task was also to be reduced to simpler components. Thus, the additional tasks had to be defined in such a way that major strategy components would be appropriate for the task.

Learning of the concepts which serve as the inputs and outputs of the processing routines is necessary to perform any tasks. This information must be available in the long term memory of the task performer. Without such information the construction of a problem space appropriate to the task would be difficult if not impossible.

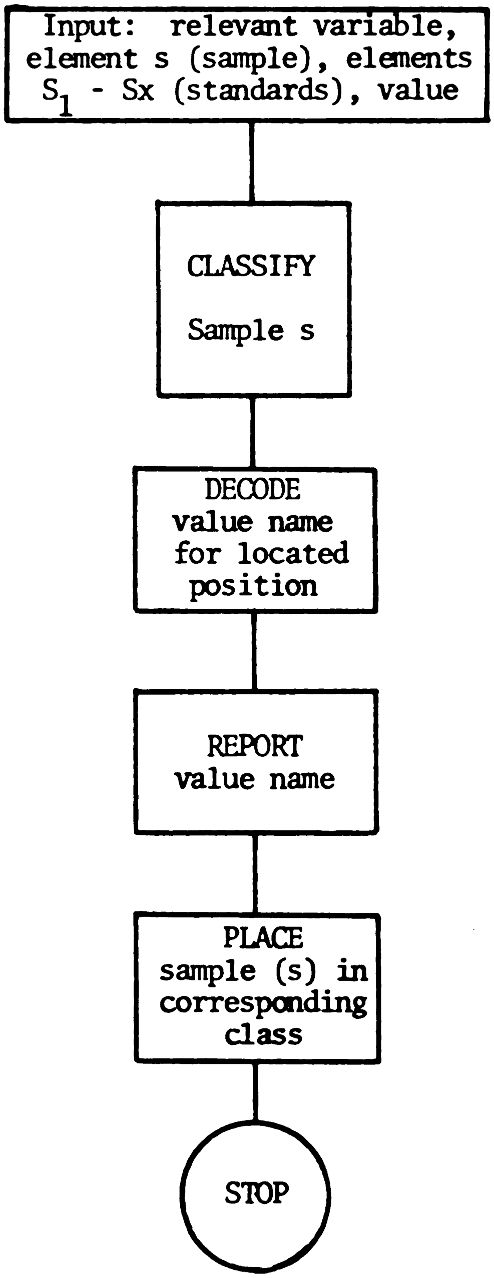


Figure 9. Single Variable Classification Task Strategy

The final task, classifying the rock samples on two variables, can be easily reduced to classifying the samples using only one variable. That is, the students are to place a given rock sample into one of three classes as delineated by the defining values and class rule. The content changes in that one variable and all attending value names are not utilized. The task is described below at both the systemic and analytic levels. The Single Variable Classification Task board is shown in Figure 10.

Single Variable Classification Task Description

Analytic Level Task		Systemic (Concept Level Exemplars	
Given	a set of elements, one relevant variable and defining values.	Given:	a set of igneous rock samples grain size, standard presenting the defining values of each class.
Output:	the elements correctly placed in the classes defined by the defining values.	Output:	each sample correctly placed in the class of which it is a member.

As just indicated the strategy for any precursor task must also be closedly related to the strategy for the final task. When compared to the strategy for the Double Variable Classification most of the strategy shown in Figure 9 can be seen as a subroutine of the more complex program.

Analysis of the second task resulted in the specification of a Comparison to Standard Task. The intent was to have students 1) make a number of discriminations by comparing samples to standard and 2) to follow the class rule for comparison to any one standard when

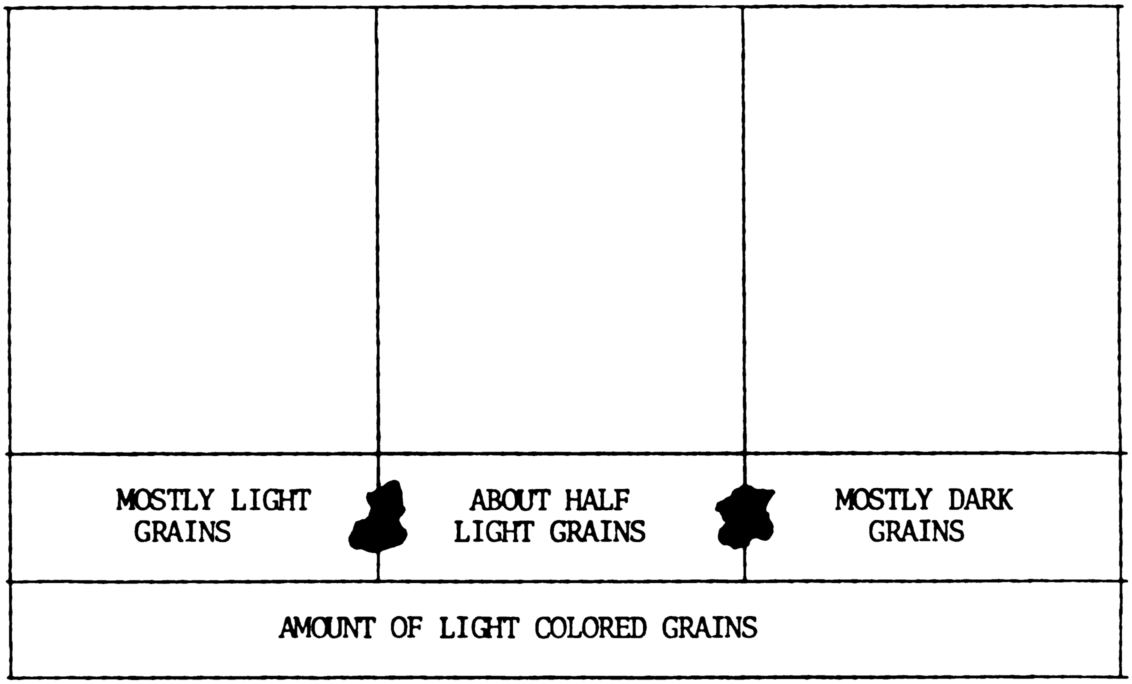


Figure 10. Single Variable Classification Chart

placing the sample in a cell. The class rule was implicit in the task environment. For example, the comparative values "larger grains" and "same size grains" were listed together for one cell while "Smaller grains" was listed for the other cell. The board for this task is shown in Figure 11.

The specification of this task is dependent to a great extent on the COMPARISON secondary process being an important subroutine in the strategy for the Single and Double Variable Classification Tasks. The task was specified in such a way that students could learn this subroutine in the context of task performance. The strategy for this task is shown in Figure 12.

Comparison to Standard Task Description

Analytic Level Task		Systemic (Concept) Level Task	
Given:	an element, relevant variable, and defining value.	Given:	granite sample, grain size, standard exhibiting, fine grained texture.
Output:	the value of the variable for the element in comparison to the defining value, i.e., greater than, less than, equal; the element placed in the corresponding cell.	Output:	the granite is more course grained than the standard (defining value).

AMOUNT OF LIGHT COLORED GRAINS	
MORE OR SAME AMOUNT OF LIGHT GRAINS	MORE DARK GRAINS

Figure 11. Comparison to Standard Chart

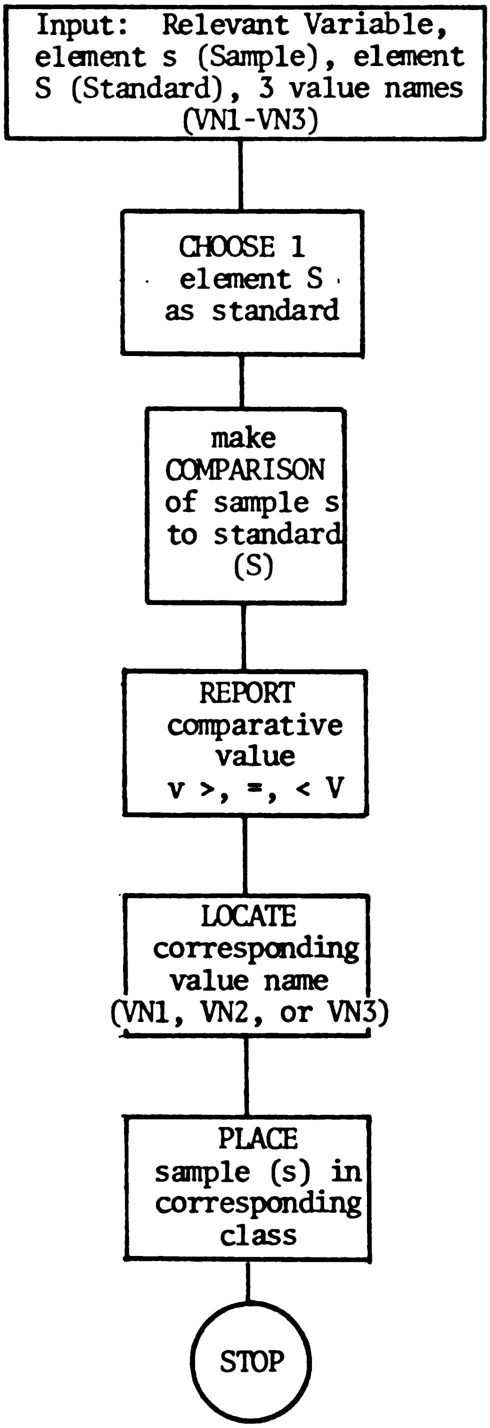


Figure 12. Comparison-to-Standard Task Strategy

In summary, the design of the instructional sequence results in two additional tasks derived from the content-task-strategy analysis of igneous rock classification. The results are dependent on both the task and strategy. The three tasks can be more generally described as follows:

Task III: DOUBLE VARIABLE CLASSIFICATION TASK

> The final task is the classification of igneous rock samples using two variables, grain size, and the relative amounts of light and dark grains. The variables are crossed to form a 3 X 3 classification chart. Each row or column is defined by specific defining values. These are represented by standard samples located on the boundaries of each row and column.

Task II: SINGLE VARIABLE CLASSIFICATION

> The second task is the classification of the samples using only one variable on a three cell classification table. Again, standard samples represent the defining values of each cell.

Task I: COMPARISON TO STANDARD

> The first task is the comparison of a single rock sample to a standard sample requiring a verbal statement as to whether the variable values for the sample are greater than, equal to, or less than the values for the standard. Also required is the correct placement of the sample in one of two cells labeled greater than or equal to, and less than.

Preliminary to any instruction on a task the content analysis and pilot study indicated a number of concepts were needed to understand the initial task instruction. In general there were the value names 1) large grains, small grains, glassy (for the variable grain size); and 2) mostly light colored grains, about half light colored grains, mostly dark grains (for the variable amount of light colored grains). In addition, for both sets of value names it was necessary to teach students to identify individual grains within each sample. For the second set of value names "light" grain and "dark" grain had to be operationally defined. Other concepts identified by the content analysis were either already known by the students or learned in the context of the preliminary task instructions. In effect the preliminary concept instruction was done for those concepts necessary to make instructions on the first tasks understandable by the students. Taken in total the preliminary concept instructions and initial task instructions were intended to make available to the student in long term memory those concepts of the discipline which were necessary for task performance as indicated in the strategy models.

Additional Related Research

The study of classification within science education has not been previously investigated from the perspective adopted in the present study. The learning and transfer of classification has been addressed primarily as developmental studies following the work of Piaget. There has been a limited number of studies which were directly compared with science content. In its place tasks taken directly from the work of developmental psychologists have been used. The studies have investigated the delineation of hierarchies of logical classification structures (Allen, 1970), the effects of a structured learning sequence on classification achievement (Raven, 1970), the effects of response format of a classification learning sequence (Popp and Raven, 1972), the development of classification abilities in culturally disadvantaged children (Raven, 1967-68), and the properties a child selects to classify pictures of various bottles (George and Dietz, 1971). To borrow a conclusion from Voelker's review of the literature on concept learning:

> "Many studies could have just as well been done by a child development specialist. . . (p. 42). An inordinate amount of research still seems to be based on the notion that it is necessary to determine how early in the curriculum certain concepts can be inserted. Unfortunately, the concern for introduction takes precedence over optimizing learning" (1973, p. 41).

More closely related to science education are the studies by Allen (1968) and Bridgham (1969). The former investigated effects of an elementary science unit from the SCIS program on students classificatory abilities; the later examined the relationship of the students understanding classification to the learning of electrostactics. Bridgham's study in particular was important as it offers an appropriate perspective for science educators in utilizing the work of development psychologists. "If Piagets work is to be used appropriately in making curricular decisions, attention must be focused on the effects of a childs developmental status on his approach to and learning of curricular content" (1969, p. 119). It is this viewpoint that points to the utility of developmental studies in the present investigation.

The work of Piaget is related to the present study in that the structures of multiple classification would seem necessary to the performance of the geologic classification task. The crucial component of this structure is the operational coordination of two properties which determine the intention of a class of objects. Without this operational structure the subjects would be likely to resort to the classification of a rock sample on the basis of a single variable.

The particular Piagetian task most like the geologic classification task is called simple multiplication or intersection and is described as follows: "(The subject) is presented with a row of green objects (a pear, a hat, etc.) and a row of leaves with various colours (brown, red, yellow, etc.) at right angles to it. An empty space is left at the point where they meet, and the subject is asked to fill the cell (the answer being in the form of a verbal description, or a free drawing, or if necessary a choice out of several alternative pictures). He has to find the object that "fits in with everything" in each of the two rows" (Inhelder and Piaget, 1964, p. 176).

The responses of students fall into two groups. The subject either takes only one of the two rows into account when deciding the element to fill the empty cell, or he takes both. Inhelder and Piaget cite the following data (1964, p. 178).

Age	5-6	7-8	9-10
Choice matches 1 collection	85%	42.5%	17.5%
Choice matches 2 collections	15%	57%	82.5%

However, for Piaget the ability to coordinate two variables does not fully define the structure for inclusion. In addition, the students must abstract the common property of a collection, i.e., determine its intention, and use the word "all" in response to questions about his choice. The later indicates the ability to consider the extension of the class. The reactions of students demonstrating both the ability to coordinate two properties and the extension--intention relationship of a class and its elements occured in the following proportions (1964, p. 184).

Age	5-6	7-8	9-10
	12.5%	30%	50%

The geologic classification task is similar in that the student must be able to coordinate two properties of class membership to correctly place a sample. Thus, lest the lack of the development of those structures preclude the performance of subjects in the geologic task, the presence or absence of the structure related to simple multiple classification must be considered in the evaluation of student performance. Bridgham (1967) in the context of investigating the relationship between childrens' classificatory abilities and their understanding of electrostatics developed a simple multiple classification test. In the present study, this test was used in considering the development of the related classification structures of the students.

In interpreting any relationship between performance on the two tasks, it must be kept in mind that the classification tasks are also different on at least two important dimensions. First the intention of the classes are obtained in two different ways. In the Piagetian task the intention is visible in a set of related objects in perpendicular rows. In the geologic task the intention of the classes must be obtained from defining values of each cell as exemplified by the standard in combination with the class rule.

Secondly, there are important differences in perception of the variables which define the class intention. The Piagetian tasks are developed in such a way as to explicate the existence of the operational or logical structures. They are, therefore, concerned with objects that clearly present the variables and values of those variables. For example, the variables are often size, shape, and color. The variable values for color may be blue, green, red, yellow, etc. Using such variables and values one encounters few problems with discrimination. Few children will have problems telling a blue square from a red triangle when working with the multiple classification task. The variables are well known and easily perceived by the students. In fact to select unfamiliar objects, unknown variables, and nearly indiscriminable values would greatly confound the major purposes in their study. However, within a disciplinary task such as geologic classification the discriminations required are not so easily made, and the variables and values are often previously unknown to the student. These are often major problems in disciplinary classification tasks.

Considering the foregoing comment, it is clear that the geologic classification is more complex in terms of the elements and concepts involved. However, because the same logical or operational structures are required the development of those structures must be considered.

CHAPTER III

RESEARCH METHODS

Overview

Students were randomly selected and randomly assigned to one of four instructional groups. One of the groups was given instruction based on model cognitive strategies for the following tasks: Comparison to Standard, Single Variable Classification, and Double Variable Classification. The other three groups were given feedback about the accuracy of their responses. Of these three groups, one was instructed on all tasks, one was instructed on the second task only, and one was instructed on the third task only. During the first contact each student received (a) instruction on concepts used in the tasks and (b) a multiple classification pretest. The students were given a pretest-instruction-posttest sequence on each task. The posttest was given on the second day. During each contact with the students data relevant to specific hypotheses were collected for statistical analysis.

The chapter includes description of the research methods of the study. There are six major sections: (1) the sampling of the subjects from the population and the assignment of the subjects to instructional groups, (2) the description of materials, (3) the procedures related to the instruction of research personnel and research subjects, (4) the experimental design, including research hypotheses, (5) the dependent variables, and (6) the statistical analyses.

Research Subjects

Sample

The sample for this study was taken from the fourth grade classes in four schools in a multi-ethnic district with a wide range of family incomes. The twenty-three urban elementary schools of this district showed enrollments of 72% Caucasian, 17% Negroid, 9% Spanish (by surname), and 1% American Indian. The mean age was 117.0 months (S. D. = 4.14 months).

The four schools were selected because the researcher had previously assisted them in a project unrelated to the present research. Practical problems of gaining access to the schools for research necessitated the use of these schools.

Students in two of the schools were in self-contained classrooms. The third school used a large single room for team teaching. In the fourth school the teachers taught specific subject areas in separate rooms, and used a modular scheduling program.

Selection and Assignment

The random selection and assignment of students and instructors was complex but necessary to assure that irrelevant variables would not vary systematically across treatment groups. All random assignment procedures were done using a table of random numbers. The assignment procedure is described below with aid of Figure 13.

Assignment was made to one of four instructional groups. The subjects assigned to the first and second groups continued throughout the three tasks of the study. The third group was used during the sessions for the second task only and the fourth group was used during the sessions for the final task only.

A total of twenty four students were chosen from each of the four schools. For the self-contained room schools twelve students were randomly selected from each of the two fourth grade rooms. Three of these twelve students from each room were randomly assigned to each of the four treatment groups. For the team taught and modular schedule schools the twenty four students were randomly selected from all fourth grade students. Six students of each twenty four were assigned to each of the four treatment groups.

Instructors and students were arranged in the following way.

Twelve instructors were divided into four teams of three. Each team of three instructors was assigned to one school. The assignment of these teams of instructors to teams and schools met the scheduling requirements of the instructors and the schools.

From the self-contained room schools, one student from each classroom and instructional group was assigned to a particular instructor. For the team teaching and modular scheduled schools, two children from each instructional group were randomly assigned to one of the three instructors. Each instructor was responsible for eight of the twenty-four students.

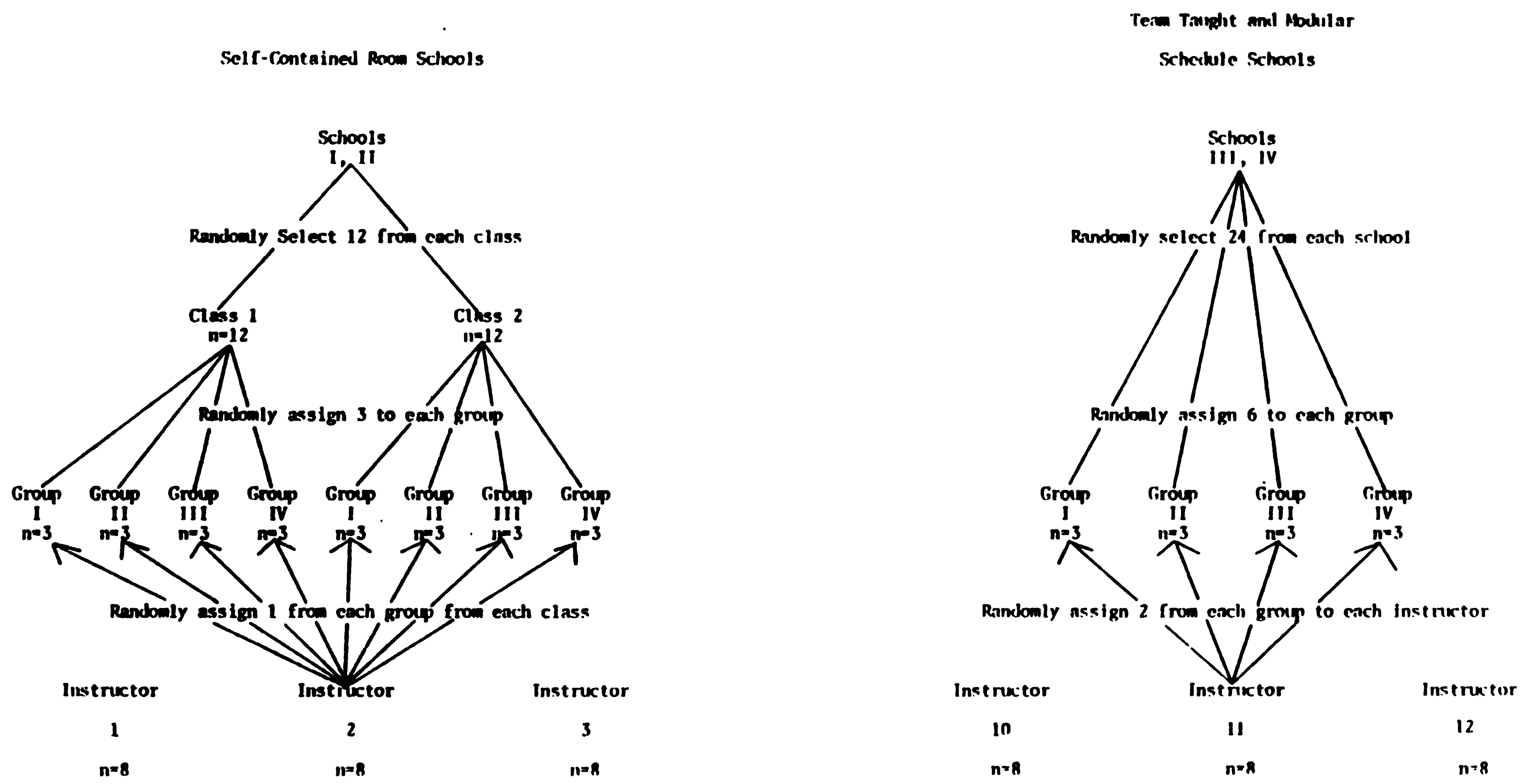


Figure 13. Random Selection and Assignment of Students

While the total number of students was ninety-six (N = 96), a mazimum of seventy-two students were in the study at any one time. This resulted from the use of three groups of twenty-four students during the second and third task. The minimum number of forty-eight students resulted from the use of only two instructional groups during the first task. Figure 14 summarizes the number of students which were instructed on each task.

Instructional Group	Task I	Task II	Task III	N
A	24	24	24	24
B	24	24	24	24
C		24		24
D			24	24
N	48	72	72	96

Figure 14. Number of Students for Each Task

In addition to these students, six substitute children were randomly selected from each school. For the self-contained classroom schools, again half these students were from each classroom. These students were used to replace those students originally selected in case of absense prior to the beginning of instruction on the first task. After a student had begun instruction in the task sequence, appropriate instruction continued following any period of absence.

MATERIALS

Multiple Classification Pretest Boards

The multiple classification pretest developed by Bridgham (1967) consisted of eight 18 inch x 18 inch white posterboard cards. Attached to each card were two perpendicular rows of posterboard shapes (triangles, squares, rectangles, circles and, cresents) which also varied in color and size. Each row had one characteristic (color, shape, or size) which was the same for all objects in the row, and two which varied across objects. The object which would have occured at the intersection of the row was absent. Also on the board were five to seven objects from which the students were to select the one which belonged in the open space. Figure 15 is an example of one of these boards. Complete descriptions of these materials are included in Appendix B.

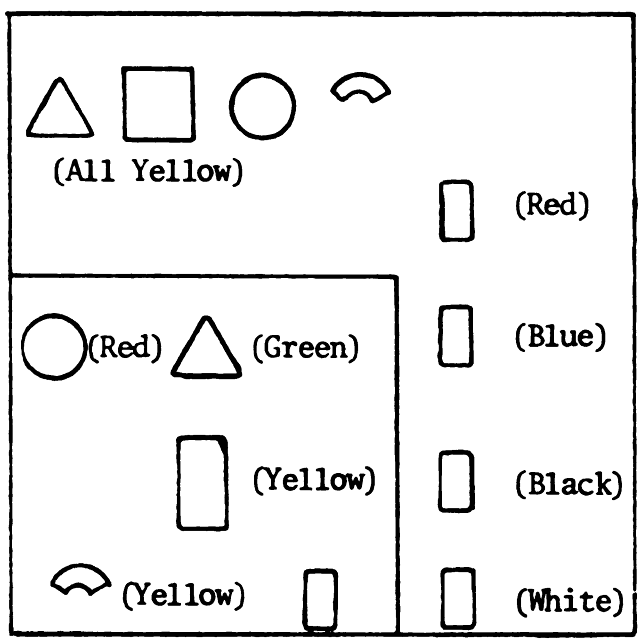


Figure 15. Multiple Classification Pretest - Sample Board

Rock Sets

The classification scheme selected for this study necessitated the selection of rock samples which could be classified on the basis of grain size and the amount of light colored grains. Samples which had a bimodal distribution of grain size could not be included. No judgment could be made by a student as to the classification of such samples using the given criteria. In addition, the rocks selected were intended to reflect the distribution of the various classes of igneous rocks.

Forty-eight field samples (1000-15,000 cm^3) were selected. These field samples were divided into two sets labeled Set A and Set B. Two sets were necessary to minimize the students learning specific rock types. Each instructor used both sets, alternating them between testing and instructional sessions.

The two sets were generated from the original forty-eight samples by randomly assigning the samples from each class to the sets. This resulted in the rocks being distributed among the eight classes as follows: Set A - 5 granites, 6 diorites, 2 gabbros, 4 rhyolites, 2 andesites, 4 basalts, 0 glass, 1 obsidian; Set B - 5 granites, 6 diorites, 2 gabbros, 4 rhyolites, 3 andesites, 4 basalts, 1 glass, 0 obsidian. One cell in the classification scheme had no representatives.

Within each of the sets rocks were judged as high, medium or low difficulty by three persons ranging in geologic experience from expert to novice. Difficulty was judged primarily on the basis of how fine a discrimination was required between the sample and the nearest standard for a given variable. The texture of the grains and lack of color constrast were also considered.

The initial random assignment to sets A and B resulted in one more highly difficult sample being assigned to Set A and one more low difficulty sample being assigned to Set B. Both being within the same class, the samples were switched to balance both sets for difficulty.

The judgment of rock difficulty was used in ordering the presentation of the samples in each set. The ordering was done to balance the rock difficulty across the twenty-four samples. Without this precaution the trials to criterion measure, to be described later, could have been systematically influenced by the consecutive occurrence of a number of rocks which were easy or difficult to classify. One sample from each difficulty category was assigned to one of seven groups of three. These seven groups were randomly ordered. This accounted for the order of twenty-one of the twenty-four samples. As two rocks of high difficulty and one of medium difficulty remained, an eighth identical group could not be generated. These samples were randomly assigned among the positions between the other seven groups. This procedure resulted in a set consisting of seven randomly ordered groups of three samples of varying difficulty, and three samples randomly inserted in the sequence.

Finally, twelve replicas of Sets A and B were made by fracturing the larger field samples into hand sample sizes (20-100 cm^3). These multiple sets were necessary to avoid the students remembering the correct placement of a sample on the basis of irrelevant criteria, such as an unusual shape.

In addition to the samples, four standards were required to represent the defining values for each cell. The two grain size standards and two amounts of light grain standards were selected so that samples placed by comparison to the standards would be geologically correct. For the Comparison to Standard task only one of each pair was required. The standard exhibiting the maximum value was selected from the pair for each variable.

Task Boards

The three task boards are shown in Figure 4, 10, and 11 (previous chapter). Each board was constructed of tan tri-wall cardboard with printed variable and variable value labels on white posterboard attached. All lines consisted of 1/4 inch black posterboard tape. The cells for each board were 8 inches x 8 inches squares. Each lettering area was 5 inches in width.

Procedures

Instructor and Tester Training

Each instructor received approximately three hours of instructions, aimed at developing an understanding of the questions and design of the study. This was expected to help instructors reach correct decisions to problematic situations in the field. The next instruction (two hours per task) was in the specific use of the protocols and scoring procedures for each task. This included verbal explanation, demonstration by the researcher and dissertation advisor, and simulation where all instructors scored one expert trainer who was completing the task. Two hours of practice with peers acting as subjects was also completed for each task. Finally the instructors worked approximately three hours with children in practicing the protocols and scoring procedures for the first two tasks. This was not necessary for the third task due to the similarity of the second and third task procedures and the field experience each instructor gained teaching children on the first two tasks. In total the instructor training, supervised by one or two expert trainers, required approximately eighteen hours. Throughout this training emphasis was placed upon the careful and complete use of the instructional protocols. Additional personnel similarly trained were utilized to posttest all students.

Classification Pretest and Preliminary Instruction*

The multiple classification pretest developed by Bridgham (1967) was administered to all children before any instruction associated with rock sample or tasks. The students were asked to look at each of eight cards and identify one of a set of objects which should be placed at the blank intersection of two perpendicular rows of objects. As described earlier, the objects in a row varied on two of three properties (color, size, shape) and was constant on a third property. The students were told that there were "two groups of things" and a space where "Something is missing" (Bridgham, 1967, p. 147). They

*Note: Complete protocols for all instructions are included in Appendix C.

were asked which of the objects from the other group should go in the blank space. Thus, to complete the task the students were required to decide the common characteristic of each row and to coordinate those two properties in selecting the object appropriate to filling the open space. The task scores were 0-8 depending on the number of cards for which the student selected the correct object. This score was to be used as a potential covariate with the scores for the Double Variable Classification Task.

During this same session students were given the instruction on concepts necessary to understanding the task instructions. This instruction was called systemic instruction and focused on teaching the students about the rocks they were to be using. The students were taught to identify a mineral <u>grain</u>, <u>large</u> grain, <u>small</u> grain, <u>glassy</u> rock, <u>light</u> and <u>dark</u> grains. Except for the concept grain, the others were the descriptive terms identifying the value for the variables grain size and amount of light colored grains. These values were used in the labels for the cells of the task boards.

To accomplish this instruction students were first shown a rock sample exemplifying the concept of interest and three examples of the concept were carefully pointed out to the student. Each student was then asked to identify three different examples of the same concept in the given sample.

A brief example of the instructions for the concepts grain and large grain follows to illustrate the above procedure. Included are the quotations from the actual protocols.

". . . Before I have you start the task, there are some things I want you to learn about rocks."

". . . Rocks are made up of grains. Look at these rocks and I'll show you what a grain is."

". . . This rock has large grains." (A rock sample with large grains is shown to the student and the instructor begins to point to three examples of a large grain carefully outlining the boundary of each grain.)

". . . This is a large grain." (point - repeat for three grains.)

". . . Can you show me three of the large grains in the rock?" (The student is handed the sample and a pencil with which to outline the three grains.)

The only exception to the above procedure was with the concept "glassy". This was operationally defined as grains which were too small to see, so the student could not point out examples. Instead, they were asked to state that rocks were called glassy when the grains were too small to see. If the student could not identify the different examples, or the instructor had any doubts as to student understanding, the instruction was repeated. The understanding of these concepts was necessary lest a lack of these basic understandings interfer with performance of the prescribed tasks.

Pretest and Posttest Instructions

All students were pretested prior to instruction on each task. This pretest also served as the general task instructions.

For each task, the pretest instructions were intended to accomplish the following:

1) Indicate what was required of the student in performing the given task. For the first task only, example values were shown to the students as a review of the earlier instruction. This was done prior to the task introduction.

2) Direct the students to use the appropriate variable or, in the case of the third task, variables.

3) Describe the function of the standards with respect to each variable value label. That is, the decision rule which defined the logical relationship between each standard and the contiguous value labels was described. One such protocol statement was, "Rocks with more or the same amount of light grains than this standard (point to standard) go in this square (point to square)."

4) For the Double Variable Classification Task these instructions were repeated for the second variable. In addition, it was pointed out that each value label was for an entire row or column and not simply for the contiguous square.

5) Indicate to the children they were to use what they had learned before to do the present task.

6) Ask the students if they had any questions.

The protocols used to make the above explanations were read to the students as the instructor pointed to appropriated portions of the task boards.

For the posttest the protocols were exactly the same as those used for the pretest.

Instructional Treatment and Treatment Groups

There were two types of instructional treatments within the study. Strategy instruction was based on the model of the cognitive strategies for each task. The other was outcome feedback instruction. This was based on the correctness of a student's response. Both treatments were designed to assure that the information concerning the requirements of the task and function of the classification chart were identical. In addition, both treatments provided equal opportunity for experience with the materials and practice on the task. The practice during instruction varied only as did the number of samples each student required to reach the criterion of task performance. The following sections describe the instruction for the feedback and strategy treatments.

Outcome Feedback Instruction

Students given outcome feedback instruction were told they would be informed if they were right or wrong on the verbal response for the first task and placement of a sample for the second and third tasks. Two demonstration examples followed. Each example was placed in the appropriate cell. The placement was explained in terms of the comparative relationship between the sample and standards defining the boundries of each class for both variables. Following each placement, the instructor responded. If the placement was correct the instructor said: "Good! This rock has larger/the same size/smaller grains than the standard and was put here (point)". If the placement was incorrect, the response was "No! This rock has larger/the same size/smaller grains than the standard and should be put here (point)." Thus, for errors the child was both told and shown what the correct response should have been. If the child made more than four successive errors, the demonstration portion of the instruction was repeated.

Strategy Instruction

The instruction for strategy treatment subjects consisted of initial verbal instructions describing the major features of the strategy the child would be asked to learn. This was followed by a demonstration of the strategy which consisted of two examples which were 'talked-through'. That is, the instructor modeled the performance of the strategy and presented a corresponding verbal explanation of the sequence of strategy steps and the decisions being made. The behavior or sequence of steps the children are expected to learn for each task follows. Reference to the classification charts (Figures 4, 10, and 11) may be helpful in reading the following descriptions.

Strategy Instruction - Task I
Comparison to Standard

The instructions for the comparison to standard task were relatively simple. The student was required to place the sample proximate to the standard and then to make a multiple number of comparisons between the two rocks. The purpose of the proximate placement was to have both rocks placed within the childs visual focus as nearly to simultaneously as possible. The multiple comparison assured the collection of sufficient information on the relative values of the variable under consideration. Both proximate placement and multiple comparisons were to facilitate the students making the correct discrimination between values.

Strategy Instruction - Task 2
Single Variable Classification

The strategy instruction for Single Variable Classification Task is contained in the description of the final Double Variable Classification Task. The only difference is that the sequence of steps is executed for only one variable.

Strategy Instruction - Task 3
Double Variable Classification

For the third task the sequence of actions began with the selection of one of the relevant variables, grain size. The student then compared the sample to the standard exhibiting the maximum value for that variable. The sample had to be placed in close proximity to the standard. The decision to be made was whether the sample has larger, the same size, or smaller grains than the standard. If the grains were larger or of equal size, the sample was to be designated as belonging in the row preceding the standard. If the grains were smaller, the next standard was to be used in the same way. Rocks with larger or the same size grains were to be designated as belonging in the second row. Rocks with smaller grains belonged in the bottom row. To facilitate encoding the decision, the child was asked to verbalize the label for the selected row. After the row was selected, the remaining variable, the amounts of light colored grains, was used. The above process is repeated until the correct column was located. By making a series of comparisons to standards sequenced according to the decision rules implicit within the task, the class of each sample could be located.

Following correct use of the strategy and correct placement of a sample, students were given feedback identical to that of the outcome feedback treatment group.

Strategy Instruction - Responses to Student Errors

The responses to various possible errors were more complex than in the Outcome Feedback Instructions. As both the correct use of strategy and correct placement were required, there were several classes of errors which resulted.

<u>Error Type I</u> - the students used the strategy correctly but made a discrimination error during one of the comparisons to a standard.

<u>Error Type II</u> - The student correctly placed the sample but did not complete the strategy correctly.

<u>Error Type III</u> - The student did not correctly place the sample and did not correctly use the strategy.

The responses to these errors consisted of two parts. The first concerned correctness of placement, the second with the strategy errors. As more than one strategy error was possible the instructor responded to the first error in the strategy performance for the sample. This was possible as the strategy use required a well defined sequence of actions.

The exact responses can be best understood in terms of the actual protocols from the Single Variable Classification Task. The responses given in Table 3 are taken directly from the protocols and listed under the error type.

Table 3. Responses to Student Strategy Errors During Instruction

---

Type I Error (If incorrect placement but child's strategy is consistent with response.)

Response: No! This rock has mostly light/about half light/mostly dark grains.

(Move the rock to standard where initial error was made.)

Be sure to take time to carefully look back and forth between the rock and the standard (point back and forth).

You should have. . . .

--placed the rock here (place).

OR

--checked this standard (point) too and placed the rock here (place).

Type II Error (If correct placement and incorrect strategy.

Response: "The rock was placed correctly but you forgot to. . ." (use one of following for first of strategy errors.)

Type III Error (If incorrect placement and incorrect strategy.

Response: No, this rock has mostly light grains/about half light grains/mostly dark grains and should have been placed here (place sample in correct cell). You forgot to. . . (use one of following for first of strategy errors.)

Error:	Response:
Not proximate to first or both standards.	"begin by putting the rock close to the first standard" (Move rock to first standard)
Not proximate to second standard when required; i.e., P2, P3 samples	"move the rock close to the second standard." (Move rock to second standard).

Table 3 (Cont'd.)

--no verbal output	"read large grains/small grains/ glassy outloud before you placed the rock in this square.
*--uses second standard when sample is correct in cell 1.	"to stop after you checked the first standard. If the rock has larger or the same size grains as this standard (point) you do have to use the next standard (point).

*This response is used only when cell 1 placement was correct. This does not count as an incorrect trial.

The instructors corrected strategy errors as they occured. This was to help the students develop the strategy by adding the smaller components a step at a time. This procedure was followed until the entire strategy had been learned by the students.

As with the feedback students, the incorrect placement of four successive samples required a readministration of the demonstration portion of the protocol.

Schedule

The investigation began three days prior to instruction on the Comparison to Standard Task with the administration of the multiple classification pretest and preliminary instruction. The preliminary instruction was to teach the concepts necessary to perform the task. Following the initial session the students began a pretest-instruction-posttest cycle. The students were pretested and then were instructed in a given task and variable on the first day of the week. A second instructional session for the same task and variable was given to students without a pretest if they did not reach criterion during the first session. The second late afternoon session was seldom required.

The following day students were posttested by personnel blind to the treatment given individual students. This two day cycle was repeated on the third and fourth instructional days using the same task, but using the second variable. The order of the variable presentation was balanced within each instructional group.

During the third instructional week when Double Variable Classification was the focus, this cycle was changed in two ways. First, a second day of instruction was scheduled for students who did not reach criterion during the first instructional session. It was anticipated that this task was substantially more difficult to learn and would require additional instructional time. Secondly, there was no need to repeat the cycle twice as both variables were combined in the task.

The complete instructional schedule including the pretest, instruction, posttest, and task variable sequence is shown in Figure 16.

		WEEK I				WEEK II				WEEK III			
Treatment \ Day	N	1	2	3	4	5	6	7	8	9	10	11	12
Group A Strategy Instruction	12	GS	LG	GS	LG	GS	LG	GS	LG	GS	GL	GS	LG
	12	LG	GS	LG	GS	LG	GS	LG	GS	LG	GS	LG	GS
Group B Feedback Instruction	12	GS	LG	GS	LG	GS	LG	GS	LG	GS	LG	GS	LG
	12	LG	GS	LG	GS	LG	GS	GS	LG	LG	GS	LG	GS
Group C Feedback Instruction	12					GS	LG	GS	LG				
	12					LG	GS	LG	GS				
Group D Feedback Instruction	12									GS	LG	GS	LG
	12									LG	GS	LG	GS
Session		PI	PO	PI	PO	PI	PO	PI	PO	PI	I2	PO	

KEY:

VARIABLES

GS - grain size
LG - amount of light grain

SESSION

PI - pretest and instruction
PO - posttest
I2 - second instruction if required

*During each of the first two weeks, second instructional sessions were completed in the late afternoon if necessary.

Figure 16. Testing and Instruction Schedule

DESIGN

The section on design is divided into three parts. The first describes the experimental and comparison groups necessary to evaluate the research questions. The second is based on two figures which describe the control of the various independent variables involved in the study. The third part explains the research design as related to the hypotheses of the study. This section also delineates the use of the three treatment groups to isolate the effects of the instructional sequence from the effects of the strategy based instruction.

Experimental and Comparison Groups

To evaluate the stated questions, three groups were required. Two comparison groups received the outcome feedback instruction, the third group received strategy instruction.

The experimental group, called the Cumulative Strategy Group (CF), received the strategy-based instructional treatment in all tasks. The first comparison group, designated as the Cumulative Feedback Group (CF), also participated in the entire sequence of three tasks. When comparisons were made between the performance of this group and the Cumulative Strategy group both groups had completed the cumulative experience with the materials, concepts, and tasks. Differences in dependent measures were attributed to the strategy basis of instruction.

The second comparison group was referred to as the Isolated Feedback group (IF). Within this group, different subjects were brought into the study for the second and third tasks. This group was required to evaluate the effectiveness of the instruction in previous tasks, and they did not receive instruction in previous tasks. This was to assure that the instruction on the vertical task sequence results in positive learning and transfer effects.

Control of Independent Variables by Design

Certain independent variables within the study were controlled by the experimental design. The relevant design considerations are presented in two diagrams. The first (Figure 17) presents the relationships between the independent variables treatment, school, instructor, and variable sequence which are briefly described below. It should be noted that for the first task, the Isolated Feedback treatment group (IF) was not in the study but was present for the Single and Double Variable Classification tasks. The relationships shown remained the same across all tasks. The number of subjects in each cell is included. The second figure illustrates the relationship between school, variable sequence, and rock set as the rock set used by the students changed across the instruction-testing sequence. The relationships shown were identical for each of the three treatment groups within each school.

The independent variables considered were:

Treatment: (TRT) The variable of major interest. There were three levels each represented by a particular experimental or comparison group: Cumulative

Strategy (CS), Cumulative Feedback (CF), Isolated Feedback (IF).

School: There were four levels of school, selected as previously described.

Instructor: (I) From a total of twelve instructors, three were assigned to each school.

Variable Sequence: (VS) This pertained only to the first two tasks in the sequence. The Comparison to Standard and Single Variable Classification tasks required separate instruction for grain size and the amount of light colored grains. The order in which the variables were presented to the students was considered. The first variable sequence (VS 1) was grain size, then amount of light colored grains. The second sequence (VS 2) was reversed.

As shown in Figure 17, treatment (TRT), the variable of major interest, was crossed with the schools to obtain a balanced design. Without this balance, school treatment interactions could have confounded interpretation of treatment main effects.

Instructors, also crossed with treatment, were, however, nested within the schools. The logistics of running the study precluded the possibility of balancing the design for instructors and schools. Differences among the instructors' performance were not expected. The possibility was minimized by the extensive training and use of precise protocols. It should be noted that instructors were not used to posttest students.

	School	I			II			III			IV				
Treatment Groups	I / VS	1	2	3	4	5	6	7	8	9	10	11	12	Numbers of Students	
IF	1	1	1	1	1	1	1	1	1	1	1	1	1	12	24
	2	1	1	1	1	1	1	1	1	1	1	1	1	12	
CF	1	1	1	1	1	1	1	1	1	1	1	1	1	12	24
	2	1	1	1	1	1	1	1	1	1	1	1	1	12	
CS	1	1	1	1	1	1	1	1	1	1	1	1	1	12	24
	2	1	1	1	1	1	1	1	1	1	1	1	1	12	
	Totals	6	6	6	6	6	6	6	6	6	6	6	6	72	72

VS - Variable Sequence

I - Instructor

Figure 17. Design to Control Major Independent Variables

Additional trained personnel were used to administer all posttest sessions, without knowing the treatment group to which students had been assigned. Each team of two testers were assigned to posttest all students in two schools. Each tester collected data on one half (3) students from each treatment group in each school.

The variable sequence was crossed with the treatment to balance difference in the difficulty for grain size or the number of light colored grains. Pilot work predicted this difference in variable difficulty.

Figure 18 indicates the manner in which two rock sets were used in the study. The use of two sets of samples was necessary to avoid

		Task I - Comparison to Standard						Task 2 - Single Variable Classification						Task 3 - Double Variable Classification			
		First Variable			Second Variable			First Variable			Second Variable			Third Variable			
School	VS	PR	I	PO	PR	I	PO	PR	I	PO	PR	I	PO	PR	I	I	PO
I	1	A	B	A	B	A	B	A	B	A	B	A	B	A	B	B	A
	2	B	A	B	A	B	A	B	A	B	A	B	A	B	A	A	B
II	1	B	A	B	A	B	A	B	A	B	A	B	A	B	A	A	B
	2	B	A	B	A	B	A	B	A	B	A	B	A	B	A	A	B
III	1	A	B	A	B	A	B	A	B	A	B	A	B	A	B	B	A
	2	B	A	B	A	B	A	B	A	B	A	B	A	B	A	A	B
IV	1	B	A	B	A	B	A	B	A	B	A	B	A	B	A	A	B
	2	B	A	B	A	B	A	B	A	B	A	B	A	B	A	A	B

Figure 18. Design to Balance Use of Sample Sets A and B

the possibility that students could remember samples from pretest to instruction or instruction to posttest. The rock sets were rotated as shown across the tasks within each treatment group. Because it was anticipated that the order in which students encountered the variable may affect either initial or later task performance, the design was balanced for this effect.

One independent variable not included in the diagram was rock set. Two sets of rock samples were utilized within the instruction and testing, Set A and Set B. The development of the sets, described in the materials section, was done to assure the sets were identical in difficulty. Furthermore, the use of the sets was balanced in the following manner. Within each school one half of the students in each treatment group were given set A, B, A for the first variable of the Comparison to Standard pretest, instruction and posttest respectively. For the second variable the sequence was B, A, B. The ordering of the set presentation was identical for the Single Variable Classification Task. The Double Variable Classification set order was A B (B) A with set B used for the second instructional session if required. The second half of each treatment group utilized the rock sets in exactly the opposite order.

Experimental Design

The experimental design in Figure 19 begins with the random assignment of subjects to treatment groups and describes all eleven contact sessions with the students. Not shown is the second variable sequence, in which half of the students in each group were presented with the variables

	Random Assignment	Multiple Classification Pretest	Preliminary Systemic Concept Instruction	Comparison to Standard						Single Variable Classification						Double Variable Classification		
				Grain Size			Light Colored Minerals			Grain Size			% Light Colored Minerals			Grain Size; % Light Minerals		
				Pretest Task 1	Instruction Task 1	Posttest Task 1	Pretest Task 1	Instruction Task 1	Posttest Task 1	Pretest Task 2	Instruction Task 2	Posttest Task 2	Pretest Task 2	Instruction Task 2	Posttest Task 2	Pretest Task 3	Instruction Task 3	Posttest Task 3
										0^{b}_{IF}	X^{b}_{IF}	0^{b}_{IF}	0^{b}_{IF}	X^{b}_{IF}	0^{b}_{IF}	0^{c}_{IF}	X^{c}_{IF}	0^{c}_{IF}
	R	0	0	0_{CF}	X_{CF}	0_{CF}	0_{CF}	X_{CF}	0_{CF}	0_{CF}	X_{CF}	0_{CF}	0_{CF}	X_{CF}	0_{CF}	0_{CF}	X_{CF}	0_{CF}
				0_{CS}	X_{CS}	0_{CS}	0_{CS}	X_{CS}	0_{CS}	0_{CS}	X_{CS}	0_{CS}	0_{CS}	X_{CS}	0_{CS}	0_{CS}	X_{CS}	0_{CS}
Dependent Variables				Accuracy	Trials to Criterion	Strategy Scores; Accuracy	Strategy Scores; Accuracy	Trials to Criterion	Strategy Scores; Accuracy	Strategy Scores; Accuracy	Trials to Criterion	Strategy Scores; Accuracy	Strategy Scores; Accuracy	Trials to Criterion	Strategy Scores; Accuracy	Strategy Scores; Accuracy	Trials to Criterion	Strategy Scores; Accuracy
Related Hypotheses					1, 3	2, 4		1, 3	2, 4	2, 4	1, 5	3, 6		1, 5	3, 6	2, 4	1, 5	3, 6
Contact Sessions		1		2		3	4		5	6		7	8		9	10		11

Figure 19. Experimental Design

light colored grains and grain size for the first two tasks. This was indicated in the previous section.

In addition to describing the sequence of instructional and testing sessions, the diagram outlines the session during which data of the specified dependent variables was collected and the hypotheses stated at each session.

Subscripts IF, CF, CS, denote the Isolated Feedback, Cumulative Feedback, and Cumulative Strategy instructional groups. The superscripts b, c for the isolated feedback indicate that individuals in Task 3 are different from those in Task 2.

Hypotheses

The hypotheses for the three tasks are stated below in two forms, a, and b, b'. The a statement is the general form of the hypotheses. The b, b' form directly implies the comparisons which will be made between groups. The b form indicates the comparison used to evaluate the possibility of positive and negative learning or transfer effects due to instruction on the task sequence. The b' form shows the comparison for evaluating the effects of strategy-based instruction within the prescribed vertical sequence.

The hypotheses are listed by task and under the corresponding number of the research question stated earlier (page 19). The research questions are reiterated below to facilitate reading of the hypotheses.

Table 4. List of Research Hypotheses

I. Strategy Learning:

When instructed on a specific strategy within a vertical task sequence, can the student learn to perform the task using that strategy?

II. Strategy Transfer:

Does a learned task-specific strategy transfer to a more complex task within a vertical task sequence, that is, will a student automatically utilize the strategy learned for a precursor task in the uninstructed attempt to perform a related, more complex task?

III. Strategy Use:

Following instruction on a task within a vertical sequence, do students use the taught strategy to perform that task?

IV. Does strategy-based instruction improve the learning of a vertical sequence of tasks? More specifically:

A. Learning Transfer:
Does strategy-based instruction enhance the transfer of learning within the task sequence?

B. Facilitation of Learning:
Does strategy-based instruction facilitate the learning of the tasks within the sequence?

C. Task Performance:
Does strategy-based instruction enhance post-test performance accuracy within the task sequence?

Comparison to Standard

Question II and IVA are not applicable to this first task as they address transfer phenomena.

Question I. Strategy Learning

1. (a) The students given Strategy Instruction will learn the strategy for Task 1.

Table 4 (Cont'd.)

(b) Eighty percent of the students in the Strategy Instruction group will meet criterion of strategy learning for Task 1.

Question III. Strategy Use

2. (a) The students given Strategy Instruction will use the taught strategy during the posttests for Task 1.

(b) Eighty percent of the students given Strategy Instruction will meet the criterion of Strategy use during the posttests on Task 3 for 80 percent of the samples.

Question IV. B. Facilitation of Learning

3. (a) The Strategy Instruction will result in the greater facilitation of learning for Task 1.

(b') Students given Strategy Instruction for Task 1, will learn to perform the task in significantly fewer trials than will the groups given Outcome Feedback Instruction on Task 1.

Question IV. C. Task Performance

4. (a) The Strategy and Outcome Feedback Instruction on Task 1 will result in greater accuracy of performance on the Task 1 posttests.

(b') The students given Strategy Instruction on Task 1 will perform the posttests with significantly greater accuracy than the students receiving Outcome Feedback Instruction on Task 1.

Single Variable Classification

Question I. Strategy Learning

1. (a) The students given Strategy Instruction will learn the strategy for Task 2.

(b) Eighty percent of the students in the Strategy Instruction group will meet criterion of strategy learning for Task 2.

Table 4 (Cont'd.)

Question II. Strategy Transfer

2. (a) The strategy for Task 1 will automatically transfer vertically to the performance of Task 2.

   (b) Eighty percent of the students given Strategy Instruction on Task 1 will meet the criterion of Task 1 strategy use during the first pretest on Task 2 for 80 percent of the samples.

Question III. Strategy Use

3. (a) The students given Strategy Instruction will use the taught strategy during the posttest for Task 2.

   (b) Eighty percent of the students given Strategy Instruction will meet the criterion of strategy use during the posttests on Task 2 for 80 percent of the samples.

Question IV. A. Learning Transfer

4. (a) The learning from both the Strategy and Feedback Instruction of Task 1 will automatically vertically transfer to the performance of the first Task 2 pretest. However, the Strategy Instruction will result in greater vertical auto-transfer within the task sequence.

   (b) The students instructed on Tasks 1 and 2 by Strategy and Outcome Feedback will perform the first Task 2 pretest with significantly greater accuracy than will the students who have not received instruction on Task 1.

   (b') The students given Strategy Instruction for Task 1 will perform the first Task 2 pretest significantly more accurately than will the group instructed by Outcome Feedback on Task 1.

Question IV. B. Facilitation of Learning

5. (a) Both the Strategy Instruction and Outcome Feedback Instruction for Task 1 will facilitate the learning on Task 2. However, the Strategy Instruction will result in the greater facilitation of learning within the task sequence.

Table 4 (Cont'd.)

(b) Students given Outcome Feedback and Strategy Instruction for Tasks 1 and 2 will learn to perform Task 2 in significantly fewer trials than will the group given Outcome Feedback Instruction on Task 2 only.

(b') Students given Strategy Instruction for Tasks 1 and 2 will learn to perform Task 2 in significantly fewer trials than will the groups given Outcome Feedback Instruction on Tasks 1 and 2.

Question IV. C. Task Performance

6. (a) Both the Strategy and Outcome Feedback Instruction on Tasks 1 and 2 will result in greater accuracy of performance on the Task 2 posttests. However, the Strategy Instruction will result in the greater accuracy of performance within the task sequence.

(b) The students given Outcome Feedback and Strategy Instruction on Tasks 1 and 2 will perform the Task 2 posttests with significantly greater accuracy than the group receiving Outcome Feedback Instruction on Task 2 only.

(b') The students given Strategy Instruction on Tasks 1 and 2 will perform the Task 2 posttests with significantly greater accuracy than the students receiving Outcome Feedback Instruction on Tasks 1 and 2.

Double Variable Classification

Question 1. Strategy Learning

1. (a) The students given Strategy Instruction will learn the Strategy for Task 3.

(b) Eighty percent of the Students in the Strategy Instruction group will meet criterion of strategy learning for Task 3.

Table 4 (Cont'd.)

Question II. Strategy Transfer

2. (a) The strategy for Task 2 will automatically transfer vertically to the performance of Task 3.

(b) Eighty percent of the students given Strategy Instruction on Task 2 will meet the criterion on Task 2 strategy use during the pretest on Task 3 for 80 percent of the samples.

Question III. Strategy Use

3. (a) The students given Strategy Instruction will use the taught strategy during the posttest for Task 3.

(b) Eighty percent of the students given Strategy Instruction will meet the criterion of strategy use during the posttest on Task 3 for 80 percent of the samples.

Question IV. A. Learning Transfer

4. (a) The learning from both the Strategy and Feedback Instruction on Task 1 and 2 will automatically vertically transfer to the performance of the Task 3 pretest. However, the Strategy Instruction will result in greater vertical auto-transfer within the task sequence.

(b) The students instructed on Tasks 1 and 2 by Strategy and Outcome Feedback will perform the Task 3 pretest with significantly greater accuracy than will the students who were not instructed on those tasks.

(b') The students given Strategy Instruction for Task 1 and 2 will perform the Task 3 pretest significantly more accurately than will the group instructed by Outcome Feedback on Task 1 and 2.

Question IV. B. Facilitation of Learning

5. (a) Both the Strategy Instruction and Outcome Feedback Instruction for Tasks 1, 2, and 3 will facilitate the learning of Task 3. However, the Strategy Instruction will result in the greater facilitation of learning within the task sequence.

Table 4 (Cont'd.)

(b) Students given Outcome Feedback and Strategy Instruction for Tasks 1, 2, and 3 will learn to perform Task 3 in significantly fewer trials than will the group given Outcome Feedback Instruction on Task 3 only.

(b') Students given Strategy Instruction for Tasks 1, 2, and 3 will learn to perform Task 3 in significantly fewer trials than will the groups given Outcome Feedback Instruction on Tasks 1, 2, and 3.

Question IV. C. Task Performance

6. (a) Both the Strategy and Outcome Feedback Instruction on Tasks 1, 2, and 3 will result in greater accuracy of performance on the Task 3 posttest. However, the Strategy Instruction will result in the greater accuracy of performance within the task sequence.

(b) The students given Outcome Feedback and Strategy Instruction on Tasks 1, 2, and 3 will perform the Task 3 posttest with significantly greater accuracy than the group receiving Outcome Feedback Instruction on Task 3 only.

(b') The students given Strategy Instruction on Tasks 1, 2, and 3 will perform the Task 3 posttest with significantly greater accuracy than the students receiving Outcome Feedback Instruction on Tasks 1, 2 and 3.

Dependent Variables

Raw Data

The raw data for each of the three tasks consisted of a sequence of coded responses to indicate the actions of students as they attempted to solve the task. The coded responses were selected to describe 1) task responses, i.e., required responses such as rock sample placement on the task board, 2) strategy responses, i.e., actions required for executing the model strategy, and 3) general responses, i.e., additional actions a student might take while searching the task board for information. This last category of coded response was somewhat general. For example, in the second task, the student might look at the left, middle, or right side of the board. This could be recorded. However, whether the student was attending to the value labels, variable labels, standards, or logical relationships between the arrangement of the squares could not be reliably determined.

Recorded on each answer sheet (Appendix D) for the instructors was the sequence of symbols which would result if a child correctly executed the task using the model strategy for each rock sample. This allowed the instructor to accurately decide if the strategy had been utilized and if the placement was correct. The instructor was to record in sequence all actions by the student in addition to or in place of strategy required actions.

The symbols instructors were to record, and a brief explanation of each are shown in Tables 5, 6, and 7, one for each task. The symbols are arranged under the previously mentioned categories. Following the figure for each task are examples illustrating how these symbols were utilized.

The Comparison to Standard Task requires that students verbally state the comparative value greater than, equal to, or less than. This

Table 5. Comparison to Standard Task - Raw Data Symbols

Task Response	
V1-3	Student responds verbally with comparative value greater than (1), equal to (2), less than (3) for comparison of sample to standard on a given variable.
P1-2	Student places sample in cell labeled greater than, equal to (1), or less than (2).
Strategy Response	
A1-x grain size	Student places sample in proximity to standard for comparison lasting 1 to x seconds counted by the instructor. A is the standard for grain size, C the standard for the amount of light colored grains.
C1-x amount of light grains	
General Response	
b	Student looks at board for information, the detail of which cannot be observed by the instructor.
S1-x	The student looks at the sample for 1-x counted seconds.

described the relationship between the sample and standard on a given variable. A coded sequence of symbols described the actions of students in performing the task. For example, the recorded sequence S4 V3 b P2 for grain size would indicate that the students had studied the sample for 4 counted seconds (S4), responded smaller grains (V3), looked at the board (b), and placed the sample in cell 2 (P2). If the student had correctly followed the strategy, the coded sequence for the same sample would have been S4 A5 V3 b P2. The only difference being the symbol A5 indicating the student placed the sample proximate to the standard for 5 counted seconds. This coded sequence of symbols can be used also to describe more varied students' actions. An example would be S4 A2 b S1 A4 b V1 P2 P1 where the student repeated a look at the sample, a comparison to the standard and a look at the board before giving the verbal response, placing the sample in cell 2 and finally moving the sample to cell 1. Such extended sequences for the first task were quite uncommon.

Table 6. Single Variable Classification - Raw Data Symbols

Task Response	
P1-3	Student places sample on cell labeled large grains (1), small grain (2), glassy (3) for grain size; or mostly light grains (1), about half light grains (2), mostly dark grains (3) for the amount of light grains.
Strategy Response	
A, B. grain size or C, D amount of light grains	Student places sample proximate to one of the two standards which define the limiting values of the three cells.
V1-3	The student reads or states the value label for the cell where the sample is to be placed.
General Responses	
S1-x	The student looks at the sample for 1 to x second counts. The second count was only recorded for the students first look at the sample.
L,M,R.	The student looked to the left, middle, or right portion of the board.

The Single Variable Classification Task required the correct placement of the rock sample in one of three cells (P1, P2, or P3) delineated by the standards and variable value labels, such as mostly light grains, about half light grains, mostly dark grains. The students instructed to use the strategy were also required to place the sample proximate to certain standards (A, B or C, D) and provide a verbal response indicating the value label where the sample was to be placed (V1, V2, V3). The instructors recorded additional data when students examined the sample (S1-x) and looked to various portions of the board (L, left; M, middle; R, right). Students were not required to state a comparative value relating the sample to each standard as they were in the first task.

Examples of correct strategy sequences for grain size would be: (1) <u>S10</u> A <u>L</u> V1 P1 (2) <u>S6</u> A B <u>M</u> V2 P2, or (3) <u>S4</u> A B V3 <u>R</u> P3. These sequences would reflect the use of the strategy as designed for the sample which should be placed in cells 1, 2, or 3 respectively. The underlined symbols indicate those actions which were not required to meet the criteria for correct strategy use. The looks to various parts of the board would not be necessary or expected after the student has learned the value labels.

A variety of other sequences were recorded varying from one as simple as S2 P3 to an extended sequence S3 A B S L R A V1 V2 P2. In the first sequence the student simply looked at the sample and directly placed the rock in the third cell of the board. The more complex set of symbols indicated the student looked at the sample (S3) made proximate comparisons to both standards (A, B) looked to both ends of the board (L, R), checked standard A a second time, and changed his mind about the correct verbal response (V1 V2) before placing the sample in the cell consistent with the last verbal response.

The Double Variable Classification Task required the correct placement of the sample in one of the nine specified cells (P1-9). The strategy model required proximate comparison to 2 to 4 standards (A, B, C, D) and verbal responses which indicated the variable value label for the row and column in which the sample belongs (V1-6). The general responses included the student looking at the sample (S1-x) and searching for information associated with variables (G, grain size; L, amount of light colored grains).

The sequence of symbols indicating the use of the exact strategy model for a sample belonging in the center class of the matrix (P5) is given as an example. This shows student actions when the use of all four standards was required. Again, the underlined symbols were not required components of the strategy. The sequence is <u>S</u>7 A B <u>G</u> V2 C D <u>L</u> V5 P5. The student looked at the sample for seven second (S7) counts and made proximate comparisons to both grain size standards (A, B) before looking at the board (G) and stating the grain size value label "small grains" (V2). Comparison to both standards for the amount of light grains (C, D) preceded the look at the board (L) to read the label "about half light grains" (V5) and the placement (P5).

Sequences showing no use of the standards (S5 L S G L P4), use of standards for one variable (S8 AB V2 L P), out of sequence verbal re-

Table 7. Double Variable Classification - Raw Data Symbols

Task Response	
P1-9	Student places the sample in one of the nine classes on the 3 x 3 classification scheme.

1	2	3
4	5	6
7	8	9

Strategy Response	
A,B,C, or D	Student places sample proximate to one of the two standards for each variable: A, B for grain size; C, D for the amount of light colored grains.
V1-6	The student reads or states the value label for the row (V1-3) or column (V4-6) where the sample is to be placed.
General Responses	
S1-x	The student looks at the sample for 1-x second counts. The second count was recorded for the student's first look at the sample.
G, L	The student looked at the side of the board where information related to the grain size variable (G) was located or to the bottom of board where information related to the variable, amount of light grains (L) was located.

sponses (S17 A C V1 V4 P1), and numerous other sequences were possible. One of the more complex responses recorded was S10 V4 S G S G S G S L S L G S G S B V1 P1.

Scores

This section defines the scores generated from the raw data.

There were four general types of scores used to evaluate the various types of hypotheses. For each type there were specific scores based on the criteria appropriate to each task. The types of scores are described below. The specific scores are described in Tables 8, 9, 10.

1. Performance Accuracy Scores indicate the degree to which the students correctly meet the task requirements such as correct placement of the rock samples.
2. Strategy Transfer Scores indicate the use of the strategy for the previous task during the first attempt to perform the subsequent task.
3. Strategy Use Scores describe the extent to which students utilized the strategy taught for that task.
4. Facilitation of Learning Scores indicates the extent of instruction necessary for students to learn to correctly perform a given task. For students receiving strategy based instruction, this includes the correct use of the strategy.

For the specific Comparison to Standard and Single Variable Classification Task scores shown in Tables 9 and 10 the following should be noted. Score labels which are followed by V1 indicate the score was calculated for the students' performance using the first variable only. Scores without such notations were the mean of the scores for each variable. The mean score was used to reflect the student performance as they used both variables, grain size and the amount of light colored grains.

Table 8. Comparison to Standard Task (I) Scores

Type of Score	Score Name	Brief Description	Score Label	When Used	Type of Hypotheses	(Ref. No.)
Performance Accuracy	Comparative Response Score	No. of samples for which a correct comparative value is reported:	1CR-V1			
		first variable	1CR-V1	Pre/Post		
		second variable	1CR-V2	Test		
		mean for both variables	1CR	Post Test	Task Performance	(4)
Stragey Transfer	(Strategy Transfer scores are not required for the first task of the sequence.)					
	Placement Accuracy	No. of samples correctly placed:				
		first variable	1PA-V1	Pre/Post		
		second variable	1PA-V2	Test		
		mean for both variables	1PA	Post Test	Task Performance	(4)
Strategy Use		No. of samples task I strategy was used:				
		first variable	1SU-V1	Pre/Post		
		second variable	1SU-V2	Test		
		mean for both variables	1SU	Post Test	Strategy Use	(2)
Facilitation of Learning	Trials to Criterion	No. of samples used before 7 of 9 were correctly compared to standard & placed using the Task I strategy:				
		first variable	1TC-V1		Strategy Learning	(1)
		second variable	1TC-V2	Instruction	Facilitation of Learning	
		mean for both variables	1TC			(3)

Table 9. Single Variable Classification Task (II) Scores

Type of Score	Score Name	Brief Description	Score Label	When Used	Type of Hypotheses	(Ref. No.)
Performancy Accuracy	Placement Accuracy	No. of samples correctly placed:				
		first variable	2PA-V1	Pretest	Learning Transfer	(4)
		second variable	2PA-V1	-------	-----------------	
		mean of both variables	2PA	Post-tests	Task Performance	(6)
Strategy Transfer	Strategy Use	No. of samples for which student applied the task I strategy.	2ST-VI	Pretest	Strategy Transfer	(2)
Strategy Use	Strategy Use	No. of samples for which student used the task II strategy:				
		first variable	2SU-V1	Post Test		
		second variable	2SU-V2	Pre/Post Test		
		mean for both variables	2SU	Post tests	Strategy Use	(3)
Facilitation of Learning	Trials to Criterion	No. of samples used before 7 of 9 were correctly placed using the task II strategy:				
		first variable	2TC-V1	Instruction	Strategy	(1)
		second variable	2TC-V2	Instruction	Learning	
		mean for both variables	2TC	Instruction	Facilitation of Learning	(5)

Table 10. Double Variable Classification Task (III) Scores

Type of Score	Score Name	Brief Description	Score Label	Where Used	Type of Hypotheses	(Ref. No.)
Performance Accuracy	Placement Accuracy	No. of samples correctly placed	3PA	Pretest Post-test	Learning Transfor	(4)
Strategy Transfer	Strategy Transfer	No. of samples for which students applied the task strategy.	3ST	Pretest	Strategy Transfer	(2)
Strategy Use	Strategy Use	No. of samples for which students applied the Task III strategy:	3SU	Post-test	Strategy Use	(3)
Facilitation of Learning	Trials to Criterion	No. of samples used before 7 of 9 were correctly placed using the Task III strategy:	3TC	Instruction	Strategy Learning Facilitation of Learning	(1) (5)

These mean scores were used for evaluation of task performance, facilitation of learning, and strategy use hypotheses. Each of these related to questions which arise during or after instruction. For learning-transfer and strategy-transfer hypotheses only, scores denoted by V1 are appropriate. The evaluation of transfer questions occurred only on the first pretest as the observations must precede instruction on the new task.

For the scores describing performance of the Double Variable Classification Task the above need not be considered. The use of both variables was required in that task.

The strategy use and strategy transfer scores require additional comment. First, the criteria for the two scores are different. The criteria for the strategy transfer scores was taken from the previous task and observed on the first pretest for the next more complex task. The criteria for strategy use, on the other hand, was based on the model strategy for the task under consideration. This score was obtained from any test following the first instruction. The detail of the criteria for strategy use and strategy transfer scores for each task are given in Table 11. Second, in each of these descriptions the term "required" has a specified meaning. "Required" indicates that observed student actions were those which would have been evident had the model strategy been executed to gain the students' placement of the sample. For strategy transfer scores the corresponding model strategy was from the previous task. For strategy use scores the model was for the task being performed. The actions had to be consistent with the student's placement of the sample. This may or may not have been correct. Discrimination errors were possible during comparisons to standards which were not errors in strategy performance.

The criteria for these scores were very stringent as they require the use of strategy as an algorithm when they perform the task. The strategy transfer scores were especially stringent as the students must have utilized the strategy learned for a previous task to develop another strategy for the more complex task. The more complex strategy must have been consistent with the requirements for the new task. For example, the Double Variable Classification Task required that both grain size and the amount of light colored grains be considered to classify a sample. The previous task required only consideration of one variable. The strategy transfer measure required the Single Variable Classification Strategy be applied to both variables. In effect, the student must not just have transferred the simpler strategy but utilized it as a chunk of information in constructing a strategy for the new task.

Examples of how the scores were derived from the raw data will clarify the criteria and how they were applied. One example for each of the strategy use scores is described. The strategy transfer scores are not exemplified as they are similar to the strategy use scores of the previous task.

The simplest of the strategy use scores was from the comparison to Standard Task. A raw data sequence such as S4 A5 V1 b P1 indicated the samples were compared to the standard for more than 4 second counts,

Table 11. Strategy Score Criteria

Task	Strategy Use	Strategy Transfer
Comparison to Standard	Sample was placed proximate to the standard for at least four second counts while making the comparison.	(not applicable)
Single Variable Classification	The sample was placed proximate to the required number of standards. The value label corresponding to the placement was reported following the comparison to the last required standard.	The sample was placed proximate to the required number of standards for at least four second counts.
Double Variable Classification	The sample was placed proximate to the required number of standards. The value label corresponding to the placement was reported for each variable. The verbal report occurred following comparison to the last required standard for each variable.	The sample was placed proximate to the required number of standards. The value label corresponding to the placement was reported following the comparison to the last required standard. This was done for both variables.

the verbal response (V1) followed directly with the placement (P1) being made consistent with that response. The proximate comparison to the standard for at least 4 second counts was the single criterial feature of the strategy use.

Strategy use for the Single Variable Classification Task was somewhat more complex. The following pairs of raw data sequences illustrate the critical features of correct strategy use: (1a) A V1 P1; (1b) B A V1 P1; (2a) A B V2 Pa (2b) B a V2 P2; (3a) A B V3 P3 (3b) B V3 P3. The pairs included only the critical features of the strategy use for placement of the samples in the first, second, and third classes respectively. The second sequence of the pair was simply the reverse of the first. This reversal of direction was the only allowed difference from instruction. Not illustrated were additional extraneous actions such as glances at various parts of the boards and the use of a second standard when it was not needed to place the samples in the first or third cells. It should be noted that the four second count requirement was not included in the strategy instructions and thus is not a requirement for strategy use.

For the Double Variable Classification Task the following illustrates correct sequences: (1) A B V3 C D V4 P1, (2) A B V2 C D V5 P5, (3) D V6 B A V2 P6, (4) A B V3 C D V4 P7. The first two sequences show no deviation from the strategy. In both cases the student checked the number of standards required in the strategy and gave the verbal response following the decision for each variable. The third sequence was correct but reversed. The student began at the minimum value standard for the amount of light grains (lower right standard on the board) instead of the maximum value standard for grain size (top standard on left side of board). The fourth sequence illustrates that a second standard (D) was used when only the C standard was needed to make the decision (V4) indicating the sample belonged in the left column (mostly light grains) on the board. This use of the extra standards was allowed as correct strategy use.

In addition to the strategy use and transfer scores which were used to directly evaluate the stated hypotheses there is another extended series of scores not described in this section. These are used to describe student behaviors in terms of portions of a strategy used or transferred in performing a task. For each component, such as the placement of a sample proximate to standards or the statement of a value label, a series of progressively less stringent more sensitive scores were computed. As the number of these scores is large they are best described in the context of discussing the various hypotheses for each task in Chapter 4.

Statistical Analysis

The statistical analysis was separated into two areas. The first involved the various comparisons between groups. The second concerned learning, use, and transfer of the strategy by those given strategy instruction.

Comparative Analysis

The comparative analysis of the Comparison to Standard task data considered only task performance and facilitation of learning hypotheses. In addition there was only one comparison to be made between the performances of strategy and Feedback students. The comparison was made using Student's t-statistic. The Single and Double Variable Classification Tasks necessitated a planned comparison analysis to evaluate hypotheses involving learning transfer, task performance, and facilitation of learning hypotheses for each task. The two comparisons were: (1) The mean of the Cumulative Feedback and Cumulative Strategy Cumulative groups vs. the Isolated Feedback group and (2) the mean of Feedback vs. Cumulative Strategy treatment groups.

These comparisons allowed evaluation of the following statements:

(1) If the average of the two groups receiving instruction on all tasks exceeded the performance of the isolated feedback group, then it can be stated that the effects of the cumulative instruction positively affected student performance. This comparison also guards against the possibility of negative transfer effects.

(2) If the strategy feedback group performed better than the outcome feedback group, then it can be stated the better performance was due to the strategy-based instruction within the task sequence and not simply to cumulative experience with materials and outcome feedback.

Completing the analysis using the above comparisons was selected as the effects of interest were specified prior to beginning the investigation. The analysis was a ONEWAY ANOVA for the a priori constrasts as calculated using the Statistical Package for the Social Sciences (Nie, et al., 1975) program. The alpha level was set at $\alpha = .05$. This was considered sufficiently large to detect differences between mean scores and yet was sufficiently small to protect against incorrectly supporting the hypotheses.

Descriptive Analysis

There were no comparison groups involved in the analysis related to the strategy learning, use, and transfer hypotheses. The hypotheses were concerned only with the performance of those students receiving the strategy based instruction. However, some scores are reported for other treatment groups as an indication of whether other students are performing the task using the model strategy or strategy components. Mean scores, standard deviations, and frequency distributions are sufficient descriptive statistics for each of these scores.

The criteria for supporting the various strategy hypotheses required 80% of students to meet the strategy learning, use, or transfer criteria for 80% of the samples. As there were 24 students in each instructional groups this means that 19 students must have give a correct performance on 19 of 24 samples for a hypothesis to be supported. Nineteen of twenty-four samples or subjects is 79% whereas twenty of twenty-four samples or subjects is 83%. The former was selected as closest to the 80% stated in the hypotheses.

CHAPTER IV

RESULTS

The questions reiterated below indicate two major areas of investigation within the study. The first three questions (I, II, III) were concerned with ability of the students given strategy based instruction (the Cumulative Strategy Group) to learn, use, and transfer the taught strategies. The related premise was that the strategy for each task would be learned, used in a posttest, and transferred to the next task in the sequence as a chunk of information. The second area of investigation was related to the accuracy of task performance. It was predicted that the availability of the strategies in long term memory would facilitate learning to perform the task accurately, enhance the posttest performance accuracy, and enhance the pretest performance accuracy of the next task (Questions IV. B, C, and A, respectively).

Research Questions

I. Strategy Learning

When instructed on a specific strategy within a vertical task sequence, can the student learn to perform the task using that strategy?

II. Strategy Transfer

Does a learned task-specific strategy transfer to a more complex task within a vertical task sequence, that is, will a student automatically utilize the strategy learned for a precursor task in the uninstructed attempt to perform a related, more complex task?

III. Strategy Use

Following instruction on a task within a vertical sequence do students use the taught strategy to perform the task?

IV. Task Performance

Does strategy-based instruction improve the learning of a vertical sequence of tasks? More specifically:

A. Learning Transfer
Does strategy-based instruction enhance the transfer of learning with the task sequence?

B. Facilitation of Learning
Does strategy-based instruction facilitate the learning of the tasks within the sequence?

C. Task Performance
Does strategy-based instruction enhance post-test performance accuracy within the task sequence?

These questions were asked for each of the three tasks in the instructional sequence: Comparison to Standard, Single Variable Classification, Double Variable Classification. The last task is the most important because learning to correctly classify igneous rock samples is central to developing a students knowledge of geology.

The results for each task are reported in two sections. The first addresses the hypotheses related to strategy learning, use, and transfer. The strategy use and transfer results included two types of scores: (1) scores which directly assess the use or transfer of the complete strategy, and (2) scores which further describe the students' behavior as it reflects their use and transfer of components or parts of the strategy. These components are related to the proximate placement of samples to standards and/or the verbal response by which students reported value labels from the task boards. The second section addressed the facilitation of learning, learning transfer, and the task performance hypotheses. The reported results are the comparisons made among the Cumulative Strategy (CS), Cumulative Feedback (CF), and Isolated Feedback (IF) groups.

Comparison to Standard Task: Strategy Results

Strategy Learning

The hypothesis* related to Question I is:

1. (a) The students given Strategy Instruction will learn the strategy for Task 1.

   (b) Eighty percent of the students in the Strategy Instruction group will meet criterion of Strategy learning for Task 1.

The Trials to Criterion Score (1TC)** indicates that 92% of the twenty-four students given strategy instruction learned to perform the Comparison to Standard Task correctly using the appropriate Strategy. The students reached the criterion for learning with an over

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*The (a) statement is a general form of the hypothesis while the (b) statement(s) represents a specific predictions.

**Note: For the first two tasks instruction was given on each of two variables. The average score for performance on both variable is reported except for scores related to transfer questions. Transfer scores are calculated from data for the first pretest of each task.

all mean of 10.50 trials (samples) or slightly more than 3 samples greater than the minimum number (7) in which criterion performance could be reached. No students required a second instructional session (i.e., more than 24 samples). The data shown in Table 12 clearly support the stated hypotheses.

Table 12. Strategy Learning Results: Trials to Criterion Scores for Cumulative Strategy Group Instruction (n = 24)

Trt Grp	Score Name	Score Label	Mean	S.D.	% of Ss learning the strategy correctly in the indicated number of samples			
					7-12 Samples	13-18 Samples	19-24 Samples	> 24 Samples
CS	TRIALS TO CRITERION*	1TC	10.50	3.53	75	21	4	0

Strategy Use

The hypothesis related to Question III is:

2. (a) The students given Strategy Instruction will use the taught strategy during the posttests for Task 1.

   (b) Eighty percent of the students given Strategy Instruction will meet the criterion of strategy use during the posttests on task 1 for eighty percent of the samples.

The Strategy Use Score (1SU) most directly evaluates the students use of the taught strategy on the posttests (Table 13). Only one student (4%) used the strategy exactly as taught on more than 80% (19) of the samples. The mean score of 5.94 (S.D.=5.24) indicates

*Note: All scores which are used to directly assess a hypothesis are presented in capital letters on the tables. Scores related to strategy components are presented in lower case letters.

that students utilized the strategy on approximately 25% of the samples. The results for this score do not support the hypothesis.

Table 13. Strategy and Component Use Results: Comparison to Standard Task Posttest (n's = 24)

Trt Grp	Score Name	Score Label	Mean	S.D.	% of Ss using the strategy or component for the indicated % of samples			
					$\leq$ 25% Samples	26-50% Samples	51-75% Samples	76-100% Samples
CS	STRATEGY USE	1SU	5.94	5.24	58(13)*	30	8	4
	Standard Use	1SDU	13.71	9.49	24(17)	21	17	37
CF	STRATEGY USE	1SU	2.50	5.09	88(50)	8	0	4
	Standard Use	1SDU	4.96	7.44	75(25)	12	0	13

* % of students using strategy or component on 0% of samples.

Strategy Component Use

Further description of student performance is indicated by the Standard Use Score (1SDU) in Table 13. This score is the number of samples placed proximate to the standard without requiring the minimum four second-counts which were part of the Strategy Use Criterion.

The comparison of a sample to the standard is considered a major component of the strategy. The mean score (13.71 samples) indicates that students used the standards for approximately 57% of the samples. Furthermore, nine of the twenty four subjects (37%) compared the sample to the standard more than 80% of the time.

The results for the Standard Use and Strategy Use scores indicate a substantial number of students were placing at least one sample proximate to the standard but not for the 4 second-count required in the complete strategy.

Comparison to Standard Task: Performance Results

Pretest

The data reported for the first pretest for Task 1 provide some description of initial task difficulty. Two scores are reported, the Comparative Response Score (CR-V1)* and the Placement Accuracy Score (PA-V1).

The mean score for CR-V1 for the Cumulative Strategy Group was 15.54 (S.D. = 4.06) samples correctly compared to the standard. The mean for Cumulative Feedback group was 16.67 (S.D. = 4.17) samples.

For the placement of the samples on the classification chart (PA-V1) the strategy students correctly placed an average of 19.25 samples (S.D. = 2.47) and the cumulative feedback students averaged 19.42 (S.D. = 2.16) correct placements. The consistently greater placement score is probably a result of judgements that a sample and standard are the "same" when the judgement "greater" was correct. The placement would be accurate for either decision.

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*Note: The symbol V1 following any score label indicates the score pertains to the students first encounter with the task, i.e., the first variable.

Considered together the 48 students correctly compared approximately 67% of the samples and correctly placed approximately 80%. The level of performance indicates the task is fairly easy to perform.

Facilitation of Learning

The hypothesis related to Question IV B. is:

3. (a) The Strategy Instruction will result in the greater facilitation of learning for Task 1.

   (b) Students given Strategy Instruction on Task 1 will learn to perform in significantly fewer trials that will the group given Outcome Feedback instruction.

The difference in the Trials to Criterion Score between the Cumulative Strategy Instruction group (CS) and the Cumulative Feedback group (CF) indicates the extent to which the strategy based instruction facilitated the learning of the Comparison to Standard Task. The data shown in Table 14 are the results of the t-test analysis of the scores.

Table 14. t-Test for Trials to Criterion Score: Comparison to Standard Task Instruction

Trt Grp	n	Mean	S. D.	Standard Error	t Value	D. F.	2-Tail t-Prob.
CS	24	10.50	3.53	0.72	0.45	46	0.656
CF	24	10.10	2.51	0.51			

The results do not support the hypothesis. The Cumulative Strategy group needed slightly more trials to criterion than the Cumulative Feedback group, but the difference was not significant (p = 0.656). There is no differential facilitation of learning attributable to the instruction given either group for the first task.

It is also apparent from the mean scores for both groups that the task is easy to learn to perform. Only a mean of three samples more than the possible minimum of 7 are required by either group of students.

Task Performance

The hypothesis related to Question IV. C. is:

4. (a) The Strategy Instruction on Task 1 will result in greater accuracy of performance on the Task 1 posttests.

   (b) The students given Strategy Instruction on Task 1 will perform the posttests with significantly greater accuracy than the students receiving Outcome Feedback Instruction on Task 1.

Both the Comparative Response Score (1CR) and the Placement Accuracy Score (1PA) are related to the students' ability to perform the task following instruction. The first score indicates the students' ability to correctly discriminate between the sample and the standard. The results of the t-test analysis are shown in Table 15. The 2-tailed probability is given as the results were in the direction opposite to that stated in the hypothesis.

Table 15. t-Test for Comparative Response Score: Comparison to Standard Task Posttests

Trt Grp	n	Mean	S. D.	Standard Error	t Value	D. F.	2-tail t-Prob.
CS	24	18.31	1.71	0.349	-1.42	46	0.163
CF	24	18.98	1.54	0.315			

The results indicate that students receiving strategy instruction did not discriminate between the variable values for a sample and a standard in a manner significantly different ($p = 0.163$) from those receiving feedback on their performance.

The results for the second score (1PA) reported in Table 16 indicate the accuracy of sample placement on the task board by both groups.

Table 16. t-Test for Placement Accuracy Score: Comparison to Standard Task Posttests

Trt Grp	n	Mean	S. D.	Standard Error	t Value	D. F.	1-tail t-Prob.
CS	24	20.35	0.93	.189	0	46	0.50
CF	24	20.35	1.31	.267			

The analysis did not indicate any significant differences ($p = 0.50$) in performance between the two groups.

Single Variable Classification Task: Strategy Results

Strategy Transfer

The Single Variable Classification Task is the first in the sequence where hypotheses related to transfer phenomena are addressed. Because the transfer scores reflect the criteria for strategy use from the previous task, discussion of the results for the strategy transfer question (II) precede discussion of the results for the strategy learning question (I).

The hypothesis related to Question II is:

2. (a) The strategy for Task 1 will automatically transfer vertically to the performance of Task 2.

   (b) Eighty percent of the students given Strategy Instruction on Task 1 will meet the criterion of Task 1 strategy use during the pretest on Task 2 for 80% of the samples.

The Strategy Transfer Score (2ST-V1) was calculated from data observed on the first pretest (i.e., the pretest for the first variable) for the second task and are reported in Table 17. The score is a stringent measure in that students must use the standards sequentially for four second-counts while placing the sample. The mean score was low ($\bar{x}$ = 1.21, S. D. = 1.91). Only one student applied the entire strategy to more than 25% of the samples. The results do not support the stated hypothesis. The Comparison to Standard strategy did not transfer as a complete chunk of information which was used in a more complex strategy based on the sequential use of the standards.

One additional strategy transfer score was calculated. The strategy count score (2SC-V1) is the number of samples for which students place the sample proximate to one or both standards for the four second counts. It is less stringent than the Strategy Transfer Score in that the students were not required to use the standards in any particular sequence. However, this score also indicates a very limited transfer of the first task strategy as only 8% of the students scores correctly for more than 25% of the samples.

Table 17. Strategy and Component Transfer Scores: Single Variable Classification Task Pretest (n's = 24)

Trt Grp	Score Name	Score Label	Mean	S.D.	% of Ss transferring strategy or component for indicated % of samples			
					≤ 25% Samples	26-50% Samples	51-75% Samples	76-100% Samples
CS	STRATEGY TRANSFER	2ST-V1	1.21	1.91	96(54)*	4	0	0
	Strategy Count	2SC-V1	3.29	4.30	92(46)	8	0	0
	Sequential Proximate Standard	2SPS-V1	7.29	7.82	67(25)	4	13	16
	Proximate Standards (1or2 std)	2PS-V1	10.00	9.47	45(21)	17	13	25
CF	STRATEGY TRANSFER	2ST-V1	0.54	1.51	100(83)	0	0	0
	Strategy Count	2SC-V1	1.82	4.38	96(71)	0	0	4
	Sequential Proximate Standards	2SPS-V1	3.08	3.56	79(46)	13	8	0
	Proximate Standards (1or2 std)	2PS-V1	4.87	7.10	71(38)	17	4	8
IF	STRATEGY TRANSFER	2ST-V1	0.21	0.83	100(92)	0	0	0
	Strategy Count	2SC-V1	0.58	2.08	96(88)	4	0	0
	Sequential Proximate Standards	2SPS-V1	1.00	3.30	96(79)	0	4	0
	Proximate Standards (1or2 std)	2PS-V1	1.62	3.79	96(67)	0	4	0

* % of students transferring strategy of component for 0% of samples.

Strategy Components Transfer

Two additional scores useful in describing the students' actions are reported in Table 17. They serve to indicate the influence of various requirements and the transfer of strategy components. These are the Sequential Proximate Standard Score (2SPS-V1) and the Proximate Standards Scores (2PS-V1).

The first score (2SPS-V1) is the number of samples for which the standards are used in sequence but without any time limitation. The mean Sequential Proximate Standards Score, which deletes the time requirement, was 7.29 samples (S.D. = 7.82). The seventy five percent (75%) of the students who sequentially used the standards for at least one sample averaged 9.72 samples (40%). When the minimum time requirement is eliminated a substantial number of students used the standards in sequence for a limited number of samples. The limiting effect of the time requirement is not surprising as it was seldom met during the Comparison to Standard posttests.

The Proximate to Standards Score is the number of samples the student placed proximate to one or both standards. This is the least stringent measure in that there is no time or sequential use of standards requirement. The mean Proximate Standards Score was 10.00 samples (S.D. = 9.47). Nineteen students (79%) averaged 12.6 samples (52%) placed proximate to at least one standard for a brief time. This result indicates that the placement of samples proximate to standards transferred to a moderate extent as a chunk of information or strategy component.

Strategy Learning

The hypothesis related to Question I is:

1. (a) The students given Strategy Instruction will learn the strategy for Task 2.

   (b) Eighty percent of the students in the Strategy Instruction group will meet criterion of strategy learning for Task 2.

The mean Trials to Criterion Score (2TC) for students receiving strategy instruction was 12.05 samples (S.D. = 4.21). All students reached criterion, i.e., learned to place the samples accurately using the strategy with a 2TC score less than 23 samples. The above hypothesis is supported by the data. This does not indicate that all students reached criterion during the sample instructional session (i.e., > 24 samples) for both variables. Two students (8%) required a second instructional session for the first variable, and one student required a second session for the second variable. However, all three students averaged less than 24 samples for the two variables combined.

Table 18. Strategy Learning Results: Trials to Criterion Score for Cumulative Strategy Group (n = 24)

Trt Grp	Score Name	Score Label	Mean	S.D.	% of Ss learning the strategy correctly in the indicated # of samples			
					7-12 Samples	13-18 Samples	19-24 Samples	> 24 Samples
CS	TRIALS TO CRITERION	2TC	12.04	4.21	58(4)*	30	12	0

* % of students learning strategy correctly in fewest possible samples (7).

Strategy Use

The hypothesis related to Question III is:

3. (a) The students given Strategy Instruction will use the taught strategy during the posttest for Task 2.

   (b) Eighty percent of the students given Strategy Instruction will meet the criterion of strategy use during the posttest on Task 2 for eighty percent of the samples.

The posttest use of the Single Variable Classification strategy by the Cumulative Strategy group was extensive, but not sufficient to confirm the hypothesis. The results for the Strategy Use Score (Table 19) show fifty eight percent of the students used the strategy as taught for more than 80% (19) of the samples. All students used the strategy for at least one sample.

Strategy Components Use

The Single Variable Classification Strategy is composed of two major observable components. The first is the use of the standards in deciding the correct classification. The second is the verbal response. The response is the report of an appropriate value label such as "large grains". The results of two scores for each component provide a closer look at the students' strategy use (Table 19).

The Sequential Standards Use Score is the number of times the student placed a sample proximate to the required number of standards in specified sequence. The Mean Score of 16.62 samples (S.D. = 6.67) is only slightly higher than the Strategy Use Score. This indicates that the use of the required standards is extensive.

Table 19. Strategy and Component Use Scores: Single Variable Classification Task Posttests (n's = 24)

Trt Grp	Score Name	Score Label	Mean	S.D.	% of Ss using strategy or component for indicated % of samples: ≤ 25% Samples	26-50% Samples	51-75% Samples	76-100% Samples
	STRATEGY USE	2SU	16.31	6.74	8(0)*	21	13	58
	Sequential Standards Use	2SSU	16.62	6.67	8(0)	17	13	62
CS	Standard Use (1or2 stds)	2SDU	19.06	5.97	0(0)	17	16	67
	Sequential Verbal Response	2SVR	18.98	7.82	4(0)	17	12	67
	Verbal Response	2VR	23.06	2.67	0(0)	4	0	96
	STRATEGY USE	2SU	3.00	5.07	83(33)	4	13	0
	Sequential Standards Use	2SSU	3.48	5.43	83(29)	4	13	0
CF	Standards Use (1or2 stds)	2SDU	5.12	6.90	75(21)	8	4	13
	Sequential Verbal Response	2SVR	4.25	6.66	79(21)	4	8	8
	Verbal Response	2VR	18.75	8.32	13(4)	12	4	71
	STRATEGY USE	2SU	0.43	1.13	100(75)	0	0	0
IF	Sequential Standards Use	2SSU	2.21	3.60	88(42)	8	4	0

Table 19 (Cont'd.)

Standards Use (1or2 std.)	2SDU	3.17	4.90	88(42)	4	8	0
Sequential Verbal Response	2SVR	0.65	1.76	100(71)	0	0	0
Verbal Response	2VR	8.25	9.58	54(33)	17	8	21

* % of students using strategy or component for 0% of samples.

The Standards Use Score is the number of samples for which the students used at least one standard. The mean was 19.06 samples (S. D. = 5.97). Eighty three percent of the students used the standards in some manner for more than 50% of the samples. Comparing the two Standards Use Scores indicates use of the standards in ways other than that prescribed by the instruction.

The second component of interest was the verbal response. The Sequential Verbal Response Score indicates the verbal response was given following comparison of a sample to a standard and preceding the placement on the board. The students reported a value label in sequence for an average of 18.98 samples. Seventy-nine percent did so for more than half the samples. If the sequence of the response is not considered, the mean Verbal Response score was 23.06 (S. D. = 2.67). That is, 96% of the students reported a value label at some point for more than 80% of the samples. Comparing the two verbal response scores shows students were often giving a verbal response at times other than that consistent with the taught strategy.

Single Variable Classification - Performance Results

This is the first task where the Isolated Feedback (IF) comparison group is added to the study. Any comparisons between various scores involve three groups of students. The planned comparison analysis isolates the effects of the instructional sequence (Cumulative Strategy and Cumulative Feedback vs. Isolated Feedback) and then the effects due to strategy based instruction within the sequence (Cumulative Strategy vs. Cumulative Feedback).

Prior to discussion of the results related to the hypotheses, it is possible to gain some indications of the task difficulty by examining the Placement Accuracy Score for the Isolated Feedback group recorded on the first pretest (Table 20).

Table 20. Placement Accuracy Results for Isolated Feedback Group: Single Variable Classification Task First Pretest (n=24)

Trt Grp	Score Name	Score Label	Mean	S.D.	% of Ss correctly placing the indicated % of samples			
					$\leq$ 25% Samples	26-50% Samples	51-75% Samples	76-100% Samples
Iso-Feedback	Placement Accuracy	2PA-V1	16.83	3.61	0	8	50	42

The results show that students new to the task can correctly place 70% of the samples following the concept and general task instructions. As this group was randomly assigned to the treatment, the results can serve as a reference point to which the later performance of this and the other groups can be compared.

Learning Transfer

The hypotheses for Question IV. A. are:

4. (a) The learning from both the Strategy and Feedback Instruction on Task 1 will automatically vertically transfer to the performance of the Task 2 pretest. However, the Strategy Instruction will result in greater vertical auto-transfer within the sequence.

   (b) The students instructed on Tasks 1 by Strategy and Outcome Feedback will perform the Task 2 pretest with significantly greater accuracy than will the students who have not received instruction on Task 1.

   (b') The students given Strategy Instruction for Task 1 will perform the Task 2 pretest significantly more accurately than will the group instructed by Outcome Feedback on Task 1.

The Placement Accuracy Score for the first pretest (2PA-V1) measures the performance accuracy of the various groups. For hypothesis b the analysis evaluates the learning transfer effects by comparing the Cumulative Strategy and Cumulative Feedback performance to the Isolated Feedback performance. Hypothesis b' is evaluated by comparing the performance of Cumulative Strategy and Cumulative Feedback groups.

The results shown in Table 21 and 22 indicate no significant differences for either comparison. Even though the differences in performance are in the predicted directions the results do not support the hypotheses. No significant transfer of learning advantage is evident for those who were instructed on the first task, and no significant advantage within the task sequence accrues to those receiving strategy based instruction.

Table 21. Learning Transfer - Placement Accuracy Results: Single Variable Classification First Pretest

Trt Group	Mean	S. D.	n	95% Confidence Interval
CS	18.54	3.23	24	17.18 to 19.91
CF	17.37	3.45	24	15.92 to 18.83
IF	16.83	3.61	24	15.31 to 18.36
Total Ungrouped Data	17.58	3.46	72	16.77 to 18.40

Table 22. Learning Transfer - Planned Comparisons for Placement Accuracy: Single Variable Classification First Pretest

Contrast	Difference Between Means	Standard Error of Difference	t-Value	D. F.	1-tail t-Prob.
$\frac{CS+CF}{2}$: IF	1.17	0.99	1.17	69	0.121
CS:CF	1.12	0.86	1.31	69	0.097

Facilitation of Learning

The hypotheses related to Question IV. B. are:

5. (a) Both the Strategy Instruction and Outcome Feedback Instruction for Task 1 will facilitate the learning for Task 2. However, the Strategy Instruction will result in the greater facilitation of learning within the Task sequence.

   (b) Students given Outcome Feedback and Strategy Instruction for Tasks 1 and 2 will learn to perform Task 2 in significantly fewer trials than will the group given Outcome Feedback Instruction on Task 2 only.

(b') Students given Strategy Instruction for Tasks 1 and 2 will learn to perform Task 2 in significantly fewer trials than will the groups given Outcome and Feedback Instruction on Tasks 1 and 2.

The Trials to Criterion Score (2TC) measures the facilitation of learning effects. The planned comparisons were the same as those for the preceding learning transfer hypothesis. The results of the analysis are given in Tables 23 and 24.

Table 23. Facilitation of Learning - Trials to Criterion Results: Single Variable Classification Task Instruction

Trt Group	Mean	S. D.	n	95% Confidence Interval
CS	12.04	4.21	24	10.27 to 13.82
CF	10.60	3.35	24	9.19 to 12.02
IF	11.29	3.84	24	9.67 to 12.91
Total	11.31		72	
Ungrouped Data		3.80		10.42 to 12.7068

Table 24. Facilitation of Learning - Planned Comparisons for Trials to Criterion: Single Variable Classification Task Instruction

Contrast	Difference Between Means	Standard Error of Difference	t-Value	D. F.	2-tail
$\frac{CS+CF}{2}$: IF	0.031	0.95	0.033	69	0.974
CS:CF	1.437	1.10	1.306	69	0.196

The hypotheses are not supported in that the differences between means are in the opposite direction to that predicted. However, the differences are not significant. There is no advantage or disadvantage for those students who receive instruction for the first task. Similarly, there is no significant advantage or disadvantage for the students who received strategy based instruction within the sequence.

Task Performance

The hypotheses related to Question IV. C. are:

6. (a) Both the Strategy and Outcome Feedback Instruction on Tasks 1 and 2 will result in greater accuracy of performance on the Task 2 posttest. However, the Strategy Instruction will result in the greater accuracy of performance within the task sequence.

   (b) The students given Outcome Feedback and Strategy Instruction on Tasks 1 and 2 will perform the Task 2 posttest with significantly greater accuracy than the group receiving Outcome Feedback Instruction on Task 2 only.

   (b') The students given Strategy Instruction on Tasks 1 and 2 will perform the Task 2 posttest with significantly greater accuracy than the students receiving Outcome Feedback Instruction on Tasks 1 and 2.

Placement Accuracy (2PA) is the single measure used to evaluate the above hypotheses. The results of the planned comparison analysis are given in Tables 25 and 26. Hypothesis b is evaluated by the comparison of the combined Cumulative Strategy and Cumulative Feedback group to the Isolated Feedback group. The hypothesis b' is evaluated by comparison of the Cumulative Strategy to Cumulative Feedback group performance.

Table 25. Task Performance - Placement Accuracy Results: Single Variable Classification Task Posttests

Trt Group	Mean	S. D.	n	95% Confidence Interval
CS	19.02	1.92	24	18.21 to 19.83
CF	18.85	2.11	24	17.96 to 19.75
IF	18.73	1.62	24	18.04 to 19.41
Total	18.86		72	
Ungrouped Data		1.87		18.43 to 19.31

Table 26. Task Performance - Planned Comparisons for Placement Accuracy: Single Variable Classification Task Posttests

Contrast	Difference Between Mean	Standard Error of Difference	t-Value	D. F.	1-tail t-Prob.
$\frac{CS+CF}{2}$: IF	0.208	0.47	0.440	69	0.331
CS:CF	0.167	0.55	0.305	69	0.381

Neither hypothesis is supported. There is no significant advantage gained on the second task from previous instruction in task sequence. Furthermore, within the task sequence no significant advantage accrued to those students who received the strategy based instruction.

Double Variable Classification Task: Strategy Results

The results discussed in this section begin with the strategy transfer results (Question II) as the criteria for strategy transfer are related to those for strategy use from the previous task. The strategy learning (Question I) and strategy use results (Question III) follow. The discussion of all strategy results pertains only to scores for the students in the Cumulative Strategy Group.

Strategy Transfer

The hypothesis related to Question II is:

2. (a) The strategy for Task 2 will automatically transfer vertically to the performance on Task 3.

   (b) Eighty percent of the students given Strategy Instruction on Task 2 will meet the criterion of Task 2 strategy use during the pretest on Task 3 for eighty percent of the samples.

The results of the Strategy Transfer Score (3ST) shown in Table 27 do not support the above hypothesis. Only 12% of the students reached the criterion of placing 80% of the samples by using the second task strategy for both of the variables involved in the Double Variable Classification Task. The mean score ($\overline{x}$ = 3.00, S. D. = 7.10) further indicates the Single Variable Classification Strategy does not become incorporated into a third task strategy as a complete chunk of information.

The Strategy Count Score (3SC) also shown in Table 27 is a second, less stringent strategy transfer measure. It is the number of samples for which students applied the second task strategy to at least one of the two variables. The group average was 6.79 samples (28%) on this

Table 27. Strategy Transfer Scores:
Double Variable Classification Pretest (n's = 24)

Trt Grp	Score Name	Score Label	Mean	S. D.	% of Ss transferring the Strategy indicated % of samples ≤ 25% Samples	26-50% Samples	51-75% Samples	76-100% Samples
CS	STRATEGY TRANSFER	3ST	3.00	7.10	88(71)*	0	0	12
	Strategy Count	3SC	6.79	8.89	71(46)	4	4	21
CF	STRATEGY TRANSFER	3ST	0.12	0.61	100(96)	0	0	0
	Strategy Count	3SC	0.62	2.30	96(88)	4	0	0
IF	STRATEGY TRANSFER	3ST	0.00	0.00	100(100)	0	0	0
	Strategy Count	3SC	0.00	0.00	100(100)	0	0	0

* % of students transferring the strategy for 0% of samples.

measure. Only 21% of the students used the strategy on at least one variable for more than 80% of the samples. Even this less stringent score indicates that the strategy was not transferred to the extent anticipated.

Strategy Component Transfer

As the complete Single Variable Classification strategy did not transfer, further description of the students' behaviors is informative. This section includes results which indicate how two components of the strategy transfered. The components are the use of the standards and the verbalization of the value labels.

The students' placement of the samples proximate to standards is important in that the standards represent the values which define the classification matrix. The transfer of this component is reflected in four scores. These scores differ in two ways: (1) whether or not the sequence of use of the standards is considered and (2) whether or not the standards for both variables is considered. All four scores are reported in Table 28.

The two scores which reflect sequential standard use are the Double Sequential Standards Scores (3DSS) and the Sequential Standards score (3SS). The former (3DSS) is the number of times a sample is placed proximate to the required number of standards for both variables. The latter score is identical except that the use of the required standards is counted when applied to one or both variables. In this way it is less stringent.

The 3DSS Scores ($\bar{x}$ = 5.17, S. D. = 8.43) shows that 46% of the students who used all required standards for at least one sample averaged 11.2 samples (47%). This indicates a moderate use of the standards in sequence. However, the Sequential Standard Score (3SS) indicates that a much larger number of students transferred the comparison-to-standards component in some form. Eighty-three percent (83%) of the students placed an average of 15.4 samples proximate to the required standards for at least one variable. The comparison of these two scores indicates students did not frequently use the standards sequentially for both variables, but did so to a moderate extent for one variable.

Table 28. Transfer of Comparison-to-Standard Component Scores:
Double Variable Classification Pretest (n's = 24)

Trt Grp	Score Name	Score Label	Mean	S.D.	% of Ss transferring the component for the indicated % of samples: ≤ 25% Samples	26-50% Samples	51-75% Samples	76-100% Samples
CS	Double Sequential Standards (Both Variables)	3DSS	5.17	8.43	71(54)*	8	8	13
	Sequential Standards (1 or 2 Variables)	3SS	12.87	8.87	29(17)	13	25	33
	Double Standards (Both Variables)	3DS	6.17	9.02	71(46)	8	0	21
	Standards (1 or 2 Variables)	3S	20.37	7.17	8(4)	8	4	80
CF	Double Sequential Standards (Both Variables)	3DSS	0.25	0.85	100(88)	0	0	0
	Sequential Standards (1 or 2 Variables)	3SS	2.96	6.08	83(58)	4	9	4
	Double Standards (Both Variables)	3DS	1.21	3.46	96(75)	0	4	0

Table 28 (Cont'd.)

	Standards Count (1 or 2 Variables)	3S	4.37	8.16	79(63)	0	0	13
	Double Sequential Standards (Both Variables)	3DSS	0.12	0.61	100(96)	0	0	0
	Sequential Standards (1 or 2 Variables)	3SS	0.66	1.28	100(63)	0	0	0
IF	Double Standards (Both Variables)	3DS	0.04	0.20	100(96)	0	0	0
	Standards (1 or 2 Variables)	3S	3.25	6.01	83(67)	8	0	0

* % of students transferring component for 0% of samples.

The last two measures of the use of the standards to not consider the order in which the standards were used. The Double Standards Score (3DS) is the number of samples for which the students used at least one standard on both variables. The second, less stringent, score requires the proximate placement of a sample to at least one standard for one or both variables. This is the Standards Score (3S).

The mean 3DS score (x = 6.17, S. D. = 9.02) is very similar to the 3DSS score described above. Likewise the distribution of the scores is nearly identical. A total of 54% of the students used at least one standard for an average of 12.2 samples. This indicates that if students used the standards on both variables, it was done in the required order.

The mean 3S score is 20.37 samples (S. D. = 7.17). Eighty percent of the students used at least one standard on the board to place more than 80% of the samples. Comparison of this score to the Sequential Standards Score (x = 12.87) indicates there was a substantial use of the standards in ways other than that implicit in the strategy instruction. Comparison to the 3DS score ($\bar{x}$ = 6.17) again indicates students are not using the standards on both variables, but are doing so for one variable.

The second strategy component of interest is the verbal response. This component was added to the strategy following the pilot work. Students encountered difficulty recalling which row/column they had decided the sample should be placed for one variable after deciding the column/row for the second variable. The reporting aloud of the value label (large grains, mostly light grains, etc.) was included on the premise it would facilitate retention of the first row/column decision in short term memory.

As with the placement of the samples proximate to the standards, the four verbal response scores fall into two categories. The first pair of scores necessitates that the response be given immediately following the students' comparison of the sample to the last standard. The second scores simply required that a response be given. The results for all scores are shown in Table 29.

Table 29. Transfer of Verbal Response Component Scores: Double Variable Classification Pretest (n's = 24)

Trt Grp	Score Name	Score Label	Mean	S.D.	% of Ss transferring the component for the indicated % of samples: $\leq$ 25% Samples	26-50% Samples	51-75% Samples	76-100% Samples
CS	Double Sequential Verbal Response (Both Variables)	3DSVR	3.37	7.77	83(71)*	4	0	13
	Sequential Verbal Response (1 or 2 Variables)	3SVR	8.29	9.58	59(42)	16	0	25
	Double Verbal Response (Both Variables)	3DVR	11.25	11.18	50(42)	0	0	50
	Verbal Response (1 or 2 Variables)	3VR	16.21	10.85	29(29)	0	4	67
CF	Double Sequential Verbal Response (Both Variables)	3DSVR	0.25	1.03	100(92)	0	0	0
	Sequential Verbal Response (1 or 2 Variables)	3SVR	0.92	3.32	96(83)	0	4	0
	Double Verbal Response (Both Variables)	3DVR	7.67	10.84	67(63)	0	4	29

Table 29 (Cont'd.)

	Verbal Response (1 or 2 Variables)	3VR	10.37	11.31	50(46)	9	4	37
	Double Sequential Verbal Response (Both Variables)	3DSVR	0.00	0.00	100(100)	0	0	0
	Sequential Verbal Response (1 or 2 Variables)	3SVR	0.00	0.00	100(100)	0	0	0
IF	Double Verbal Response (Both Variables)	3DVR	2.08	6.61	92(83)	0	0	8
	Verbal Response (1 or 2 Variables)	3VR	2.83	7.04	88(67)	0	4	8

* % of students transferring component for 0% of samples.

The Double Sequential Verbal Response Score (3DSVR) is the number of samples for which the student gave a verbal response at the correct time for both variables. The second score, Sequential Verbal Response Score (3SVR) is identical except that it required one or both responses be made.

The 3DSVR results indicate that 29% of the students gave both responses in the correct sequence for one or more samples. Students clearly did not transfer the required verbal responses to both variables.

Considering the response for one or both variables the 3SVR score indicates a total of 58% gave the required verbal response for at least one variable for one or more samples. These students average 14.21 (58%) samples. This is interpreted as a moderate degree of transfer of the verbal response strategy component to at least one variable in sequence.

The second pair of scores consists of the Double Verbal Response (3DVR) and Verbal Response (3VR) scores. They are the number of samples for which the students gave a verbal response at any time for both variables or at least one variable respectively. Comparing these two scores indicates that the verbal response was used more extensively on at least one variable than on both variables. Seventy-one percent of the students gave the response on at least one variable for an average of 22.8 samples. Fifty-eight percent gave a verbal response on 19.28 samples on both variables.

Comparing the scores which required the verbal response in sequence with those that did not (3DSVR vs. 3DVR, 3SVR vs. 3VR) indicates that the verbal response frequently did not follow the final placement of the sample proximate to a standard as taught. For example, the mean number of samples where a response was given in sequence for at least one variable was 8.29 whereas the mean for giving a response out of sequence for at least one variable was 16.21 samples.

Strategy Learning

The hypothesis related to Question I is:

1. (a) The students given Strategy Instruction will learn the strategy for Task 3.

   (b) Eighty percent of the students in the Strategy Instruction group will meet criterion of strategy learning for Task 3.

This hypothesis relates to whether students could learn to use the model strategy to perform the Double Variable Classification task accurately. The Trials to Criterion score (Table 30) indicates that all students receiving strategy instruction reached criterion within the two instructional sessions. During the first instructional session eighty-three percent (83%) of the students met criterion by correctly placing 7 of 9 consecutive samples using the taught strategy. Thus, the hypothesis is supported.

The mean Trials to Criterion was 17.17 samples for the Cumulative Strategy group. The increased number of trials required in comparison to the previous two tasks (1TC = 10.50, 2TC = 12.04) indicates increased difficulty in learning to accurately perform the task using the corresponding strategy.

Table 30. Strategy Learning Results: Trials to Criterion Score for Cumulative Strategy Group (n = 24)

Trt Grp	Score Name	Score Label	Mean	S.D.	% of Ss learning strategy correctly in the indicated number of samples: 7-12 Samples	13-18 Samples	19-24 Samples	> 24* Samples
CS	TRIALS TO CRITERION	3TC	17.17	9.79	38	37	8	17

*Note: Greater than 24 samples implies students required a second instructional session.

Strategy Use

The hypothesis related to Question III is:

3. (a) The students given Strategy Instruction will use the taught Strategy during the posttest for Task 3.

   (b) Eighty percent of the students given Strategy Instruction will meet the criterion of strategy use during the posttest on Task 3 for 80 percent of the samples.

The Strategy Use Score (3SU) results for the Cumulative Strategy group (Table 31) do not support the hypothesis. Only 25% of the students used the strategy on more than 80% of the samples. The mean number of samples for the entire group was nearly half ($\bar{x}$ = 11.67, S. D. = 8.66) with only 3 students (13%) not using the strategy on any samples. Fifty percent of the students used the strategy on more than 50% of the samples. This indicates a moderate use of the strategy by a moderate number of students.

Strategy Component Use

The first strategy component of interest is the students' use of the standards. The first of two scores is the Sequential Standards Use Score (3SSU) which is the number of samples the students place proximate to the required standards for both variables in the taught sequence. The mean score of 13.50 (S. D. = 8.25) shows students used the required standards for 56% of the samples. Only two students (8%) fail to use the required standards on any samples, while 37% did so for more than 80% (19). This indicates that the students used the required standards to a moderate extent.

Table 31. Strategy and Component Use Scores: Double Variable Classification Task Posttest (n's = 24)

Trt Grp	Score Name	Score Label	Mean	S.D.	% of Ss using strategy or component for indicated % of samples: ≤ 25% Samples	26-50% Samples	51-75% Samples	76-100% Samples
CS	STRATEGY USE	3SU	11.67	8.66	38(13)*	12	25	25
	Sequential Standards Use	3SSU	13.50	8.25	25(8)	21	17	37
	Standards Use (1 or 2 stds. for both Variables)	3SDU	17.04	8.86	21(8)	8	8	63
	Sequential Verbal Response	3SVR	14.83	9.86	33(13)	4	4	59
	Verbal Response	3VR	21.62	6.57	8(4)	0	0	92
CF	STRATEGY USE	3SU	0.00	0.00	100(100)	0	0	0
	Sequential Standards Use	3SSU	1.12	4.52	96(88)	0	0	4
	Standard Use (1 or 2 stds. for both Variables)	3SDU	1.46	5.15	92(88)	4	0	4
	Required Verbal Response	3SVR	0.00	0.00	100(100)	0	0	0
	Verbal Response	3VR	10.92	11.61	50(50)	4	0	46

Table 31 (Cont'd.)

	STRATEGY USE	3SU	0.00	0.00	100(100)	0	0	0
	Sequential Standard Use	3SSU	0.21	0.66	100(88)	0	0	0
IF	Standard Use (1 or 2 stds. for both Variables)	3SDU	0.42	1.21	100(88)	0	0	0
	Sequential Verbal Response	3SVR	0.04	0.20	100(96)	0	0	0
	Verbal Response	3VR	3.42	7.80	83(75)	4	0	13

* % of students using strategy or component for 0% of samples.

The second score for examining the proximate placement of samples to standards is the Standards Use Score (3SDU). This is the number of samples for which students used at least one standard on both variables. This score is independent of the standards being used in any particular sequence. On the basis of this score the use of the standards in making placement decisions can be considered extensive. The mean score was 17.04 samples (S. D. = 8.86). Sixty-three percent scored correctly on more than 75% of the samples. The comparison of 3SSU and 3SDU indicates students were placing samples proximate to standards in ways other than that dictated by the taught strategy.

The second component of interest is the verbal response. The first score addresses the question of whether the verbal response was given in sequence. The Sequential Verbal Response Score (3SVR) is the number of samples for which a student gave the verbal response directly following the last comparison to a standard for both variables. The mean score was 14.83 (S. D. = 9.86). Fifty-nine percent of the students gave both required responses in sequence on more than 80% of the samples. This again indicates a moderate use of this strategy component as required by the model strategy.

The Verbal Response Score (3VR) simply requires that students give both verbal responses regardless of sequence. As with the use of standards, there is a substantial increase in the mean of this less restricted score. The 3VR mean was 21.62 samples (S. D. = 6.57) with 92% of the students stating two value labels for more than 80% of the samples. This indicates extensive use of the verbal response component but only to a moderate extent within the sequence specified in the model strategy.

Double Variable Classification Task: Performance Results

With respect to the design of the study there are two reminders. The task now utilizes both variables simultaneously to form the classification matrix. Thus, there are no scores which are an average of the two variables separately as there were with the first two tasks. Secondly, the students in the Isolated Feedback group were students who had not participated in instruction on previous tasks.

Considering the initial pretest performance of the Isolated Feedback group it is again possible to gain some indication of the task difficulty. The students averaged placing 8.50 samples correctly.

The difficulty of this task is substantially greater than that of the previous two tasks where comparable groups of students correctly responded for 16.1 and 16.8 samples respectively.

Multiple Classification Pretest Scores

The original plan for the analysis called for using the Piagetian Pretest Scores as a covariate for the Double Variable Classification Task Placement Accuracy Scores.

As indicated in the second chapter a positive relationship between the scores was expected. However, the Pearson Correlation Coefficient across all subjects was 0.075 and non-significant (s = 0.23). As a result Piagetian Pretest Score was not used as a covariate for the analysis comparing group performance.

Learning Transfer

The hypotheses related to Question IV. A. are:

4. (a) The learning from both the Strategy and Feedback Instruction on Task 1 and 2 will automatically vertically transfer to the performance of the task 3 pretest. However, the Strategy Instruction will result in greater vertical auto-transfer within the task sequence.

(b) The students instructed on Tasks 1 and 2 by Strategy and Outcome Feedback will perform the Task 3 pretest with significantly greater accuracy than will the students who were not instructed on those tasks.

(b') The students given Strategy Instruction for Task 1 and 2 will perform the Task 3 pretest significantly more accurately than will the group instructed by Outcome Feedback on Task 1 and 2.

The Performance Accuracy Score (3PA) for the third task was used to evaluate the transfer of previous learning within the task sequence (hypothesis b) and specifically the effects on performance attributable to the strategy based instruction (hypothesis b'). Table 32 presents descriptive statistics for each of the instructional groups separately. The results of the planned comparison analysis are shown in Table 33.

Table 32. Learning Transfer - Placement Accuracy Results: Double Variable Classification Pretest

Trt Group	Mean	S. D.	n	95% Confidence Interval
CS	13.54	4.88	24	11.48 to 15.60
CF	12.37	4.21	24	10.60 to 14.15
IF	8.50	4.62	24	6.55 to 10.45
Total	11.47		72	
Ungrouped Data		5.01		10.30 to 12.65

Table 33. Planned Comparisons for Pretest Accuracy: Double Variable Classification Pretest

Contrast	Difference Between Means	Standard Error of Difference	t-Statistic	D. F.	1-tail t-Prob.
$\frac{CS+CF}{2}$: IF	4.458	1.44	3.896	69	0.000
CS:CF	1.167	1.32	0.883	69	0.190

The comparison between scores of the combined strategy and feedback treatment groups and the iso-feedback group was significant at p = .000 indicating transfer effects of cumulative instruction within the task sequence were not chance occurences. However, the comparison between the scores for strategy and feedback children were not significant (p = 0.190). Thus, no added advantage was found in the accuracy of sample placement for the strategy based instruction when students attempted to apply the previous learning to the new task.

Facilitation of Learning

The hypotheses related to Question IV. B. are:

5. (a) Both the Strategy Instruction and Outcome Feedback instruction for Tasks 1, 2, and 3 will facilitate the learning of Task 3. However, the Strategy Instruction will result in greater facilitation of learning within the task sequence.

   (b) Students given Outcome Feedback and Strategy Instruction for Tasks 1, 2, 3, will learn to perform task 3 in significantly fewer trials than will the group given Outcome Feedback Instruction on Task 3 only.

   (b') Students given Strategy Instruction for Tasks 1, 2, and 3 will learn to perform Task 3 in significantly fewer trials than will the groups given Outcome Feedback Instruction on Tasks 1, 2, and 3.

The planned comparison analysis supports the first hypothesis but not the second (Tables 34 and 35). The difference between the Trials to Criterion Score for the Cumulative Strategy and Cumulative Feedback groups when compared to scores of those not having instruction or previous tasks was significant (p = 0.004). However, the comparison between the scores for the Cumulative Strategy and Cumulative

Table 34. Facilitation of Learning - Trials to Criterion Results: Double Variable Classification Instruction

Trt Group	Mean	S. D.	n	95% Confidence Interval
CS	17.17	9.78	24	13.03 to 21.30
CF	15.50	6.54	24	12.74 to 18.26
IF	22.83	11.95	24	17.79 to 27.88
Total	18.50		72	
Ungrouped Data		10.058		16.14 to 20.86

Table 35. Planned Comparison for Trials to Criterion: Double Variable Classification Instruction

Contrast	Difference Between Mean	Standard Error of Difference	t-Statistic	D. F.	t-Prob.
$\frac{CS+CF}{2}$: IF	-6.500	2.42	-2.684	69	0.004 (1-tailed value)
CS:CF	1.667	2.80	0.596	69	0.553 (2 tailed value)

Feedback students was in a direction opposite to that predicted. The Cumulative Strategy students required more trials than did the Cumulative Feedback students, but that difference was not significant (p = 0.553). It is evident that the cumulative effects of instruction on the structurally similar precursor tasks facilitated the learning of the more complex task. No differential facilitation of learning effect, either positive or negative, is evident between the cumulative strategy and cumulative feedback instruction.

Task Performance

The hypotheses related to Question IV. C. are:

6. (a) Both the Strategy and Outcome Feedback Instruction on Tasks 1, 2, and 3 will result in greater accuracy of performance on the Task 3 posttest. However, the Strategy Instruction will result in the greater accuracy of performance within the task sequence.

   (b) The students given Outcome Feedback and Strategy Instruction on Tasks 1, 2, and 3 will perform the Task 3 posttest with significantly greater accuracy than the group receiving Outcome Feedback Instruction on Task 3 only.

   (b') The students given Strategy Instruction on Task 1, 2, and 3 will perform the Task 3 posttest with significantly greater accuracy than the students receiving Outcome Feedback Instruction on Tasks 1, 2, and 3.

The results of the posttest placement accuracy analysis are shown in Tables 36 and 37.

Table 36. Task Performance - Placement Accuracy: Double Variable Classification Posttest

Trt Group	Mean	S. D.	n	95% Confidence Interval
CS	16.25	2.83	24	15.05 to 17.45
CF	13.79	3.80	24	12.19 to 15.49
IF	13.83	3.13	24	12.51 to 15.15
Total	14.62		72	
Ungrouped Data		3.43		13.82 to 15.43

Table 37. Planned Comparison for Placement Accuracy: Double Variable Classification Posttest

Contrast	Difference Between Mean	Standard Error of Difference	t-Statistic	D. F.	1-tailed t-Prob.
$\frac{CS+D}{2}$	Not carried out because CF was not larger than IF				
CS:CF	2.46	0.946	2.579	69	0.005
CS:IF	2.42	0.862	2.750	69	0.004

Examination of the mean scores revealed that, contrary to the prediction, the Cumulative Feedback (CF) group did no better than the Isolated Feedback (IF) group. As a result the comparison of the combined Cumulative Strategy (CS) and Cumulative Feedback scores with the Isolated Feedback scores would not be informative. Instead the CS group by itself was compared to the IF group as well as to the CF group. As indicated in Table 37, the CS group mean was significantly greater than the means of both the CF and IF groups.

These results do not support the first hypothesis as stated since feedback instruction on the task sequence did not improve posttest performance. However, strategy instruction on the sequence did improve posttest performance. The second hypothesis was supported. The strategy based instruction on the task sequence did result in better posttest performance than feedback instruction on the task sequence. The conclusion is that no advantage in posttest accuracy accrued to the students having instruction for the entire sequence unless they received the strategy based instruction.

Summary of Results

This section summarizes the results just presented. The results which most directly address the research questions are given first and summarized in Tables 38-43. Results related to students' use and transfer of strategy components are given next and summarized in Tables 44 and 45.

The results related to the research questions support the following statements:

1) The students learned to correctly place the rock samples using the appropriate strategy during instruction for all tasks.

2) The complete strategy was not used on the posttest(s) as extensively as predicted. The strategy was used to a moderate degree for the Single Variable Classification Task and to a lesser extent for the Double Variable Classification Task.

3) The complete strategy for precursor tasks did not transfer to the more complex tasks in the sequence. However, components of the taught strategy did transfer to a moderate extent.

4) The students who had participated in the entire task sequence did learn to perform the more complex Double Variable Classification Task more easily than students who did not. However, there was no facilitation of learning effect due to the strategy based instruction for any of the three tasks.

5) The students' ability to perform the more complex second task prior to instruction was not enhanced either by instruction on the simpler comparison to standard task or by the strategy based instruction within the sequence. However, transfer of learning to the final classification task is enhanced by instruction on the previous two tasks.

6) There was no posttest task performance advantage for any group during the first two tasks. On the final task there was a task performance advantage for those students receiving strategy based instruction with the task sequence.

Table 38. Summary of Strategy Learning Results:
Trials to Criterion Scores-Instruction

Task	Trt Grp	Score	Mean	S.D.	% Ss Learning strategy in ≤ 24 samples	Results
Comparison to Standard	CS	1TC	10.50	3.53	100	Ss learn to perform strategy accurately
Single Variable Classification	CS	2TC	12.04	4.21	100	Ss learn to perform strategy accurately
Double Variable Classification	CS	3TC	17.17	9.79	83*	Ss learn to perform strategy accurately

*All students learned the strategy in ≤41 samples

Table 39. Summary of Strategy Use Results:
Strategy Use Scores - Posttests

Task	Trt Grp	Score	Mean	S.D.	% Ss with Score ≥ 80%	Results
Comparison to Standard	CS	1SU	5.94	5.24	8	Complete strategy was not used.
Single Variable Classification	CS	2SU	16.31	6.74	58	Complete strategy was used moderately.
Double Variable Classification	CS	3SU	11.67	8.66	25	Complete strategy was used moderately.

Table 40. Summary of Strategy Transfer Results: Strategy Transfer Scores - First Pretests

Task	Trt Grp	Score	Mean	S.D.	% Ss with Score ≥ 80%	Results
Comparison to Standard	CS	Transfer question is not applicable to task.				
Single Variable Classification	CS	2ST-V1	1.21	1.91	0	Complete strategy did not transfer
Double Variable Classification	CS	2ST	3.00	7.10	12	Complete strategy did not transfer

Table 41. Summary of Facilitation of Learning Results: Trials to Criterion Scores - Instruction

Trt Grp	Score	Mean	S.D.	Comparison	t-Prob.	Results
		Task 1: Comparison to Standard				
CS	1TC	10.50	3.53	CS:CF	0.656 (2-tailed)	No strategy instruction advantage.
CF	1TC	10.10	2.51			
		Task 2: Single Variable Classification				
CS	2TC	12.04	4.21	$\frac{CS+CF}{2}$: IF	0.974 (2-tailed)	No task sequence advantage.
CF	2TC	10.60	3.35			
IF	2TC	11.29	3.84	CS:CF	0.196 (2-tailed)	No strategy instruction advantage within task sequence.
		Task 3: Double Variable Classification				
CS	3TC	17.17	9.78	$\frac{CS+CF}{2}$: IF	0.004 (1-tail)	Task sequence advantage
CF	3TC	15.50	6.54			
IF	3TC	22.83	11.95	CS:CF	0.276 (2-tailed)	No strategy instruction advantage within task sequence.

Table 42. Summary of Learning Transfer Results: Performance Accuracy Scores - First Pretest

Trt Grp	Score	Means	S.D.	Comparison	1-tailed prob.	Results
			Task 1: Comparison to Standard			
	(Transfer Question is not applicable to this task)					
			Task 2: Single Variable Classification			
CS CF	2PA-V1 2PA-V1	18.54 17.37	3.23 3.45	$\frac{CS+CF}{2}$: IF	0.121	No task sequence advantage
IF	2PA-V1	16.83	3.61	CS:CF	0.097	No strategy advantage within task sequence.
			Task 3: Double Variable Classification			
CS CF	3PA 3PA	13.54 12.37	4.88 4.21	$\frac{CS+CF}{2}$: IF	0.000	Task sequence advantage
IF	3PA	8.50	4.62	CS:CF	0.190	No strategy advantage within task sequence.

Table 43. Summary of Task Performance Results: Posttest Performance Accuracy Scores

Trt Grp	Score	Mean	S.D.	Comparison	1-tailed prob.	Results
			Task 1: Comparison to Standard			
CS CF	1CR 1CR	18.31 18.93	1.71 1.54	CS:CF	0.163 (2-tailed value)	No strategy instruction advantage.

Table 43 (Cont'd.)

		Task 2: Single Variable Classification				
CS CF	2PA 2PA	19.02 18.85	1.92 2.11	$\frac{CS+CF}{2}$: IF	0.331	No task sequence advantage.
IF	2PA	18.73	1.62	CS:CF	0.381	No strategy advantage within task sequence.
		Task 3: Double Variable Classification				
CS CF	3PA 3PA	16.25 13.79	2.83 3.80	CS:IF	0.004	Cumulative strategy instruction advantage
IF	3PA	13.83	3.13	CS:CF	0.005	Strategy advantage within task sequence

As indicated in the second and third statements above students did not use and transfer the complete strategies as extensively as predicted. However, they did use and transfer components of the strategies as described below. To facilitate the summary the following convention is used. The possible range of all strategy related scores is divided into upper (17-24), middle (9-16), and lower thirds (0-8). The terms extensive, moderate, and limited are used to describe the mean of each score.

Strategy use and strategy component use scores are summarized in Table 44. It is important to recall that there are two types of strategy component use scores. One type indicates that the components occured in the required sequence. The other indicates simply that the use of the component occurred.

The strategy use (1SU) for the first task was limited. This is possibly due to the 4 second count requirement which was seldom achieved. The students did make the comparisons to standard (1SDU) to a moderate extent.

For both the Single and Double Variable tasks the strategy use (2SU, 3SU) was moderate. The use of standard component in the required sequence (2SSU, 3SSU) was also moderate for both tasks. Not considering a required sequence of actions, the use of standards was extensive (2SDU, 3SDU). The pattern of scores for the verbal response component differs only in that the response was given in the required sequence extensively (2SVR) during the second task. For both tasks the verbal response scores were greater than the comparable use of standards component scores. The important point is that scores which were not restricted by the requirement of sequential actions showed an extensive use of both components for both tasks.

The strategy and strategy component transfer scores are summarized in Table 45. The first task strategy transferred only to a very limited extent to the Single Variable Classification Task. The strategy count score (3SC-V1) indicated the strategy limited transfer to even one of the two standards. The transfer of the proximate-to-standard component was limited if its use with required number of standards is the criterion. However, there was a moderate transfer of this component to at least one standard.

The strategy for the Single Variable Classification task transferred only to a limited extent to both variables (3ST) or to one variable

(3SC) of the Double Variable Classification task. For discussion of the transfer of the components to this final task it is best to separate the results into two groups. The first contains the scores which required the component be transferred to both variables on the classification scheme. The second contains scores which required the component to be transferred to only at least one variable.

With respect to the former group, the standards (3DSS) and verbal response (3DSVR) occurred in the required sequence only to a limited extent. The component transfer was also counted without considering a required sequence of actions. The comparison-to-standard components (3DS) transferred to a limited extent to both variables. Verbal responses (3DVR-V1) transferred to a moderate extent.

However, the second category of results indicates students were using the required standards (3SS) and verbal responses (3SVR) for at least one variable to a moderate extent. Not considering a required sequence indicates extensive use of at least one standard for at least one variable (3S). The same is true for the verbal response component (3VR).

There are two important points to note. First, there was a moderate transfer of the comparison-to-standard component from the first task to the second task for at least one of the two standards which could have been used. However, the component was not transferred to the number of standards which would have been required by the class rules if the strategy the students were using was a sequential repetition of the first task strategy. Second, there was a moderate transfer of the second task strategy components to at least one variable for the third task. However, the components were not transferred to both variables. The students did not sequentially apply the components to both variables as if the Double Variable task was composed of two Single Variable tasks.

Table 44. Summary of Strategy and Strategy Components Use Results for Posttests

Task	Score	Score Description	Mean	Extent of Use
Comp to Standards	1SU	Samples placed proximate to standard for 4 sec-counts	5.94	limited strategy use
	1SDU	Sample placed proximate to standard	13.71	moderate component use
Single Var. Classification	2SU	Samples placed by use of complete strategy	16.31	moderate strategy use
	2SSU	Samples placed by use of required standards	16.62	moderate component use
	2SDU	Samples placed by using at least one standard	19.06	extensive component use
	2SVR	Verbal response given in required sequence.	18.98	extensive component use in sequence
	2VR	Verbal response given.	23.06	extensive component use
Double Var. Classification	3SU	Samples placed by use of complete strategy	11.67	moderate strategy use

Table 44 (Cont'd.)

	3SSU	Samples placed by use of required standards	13.50	moderate component use in required sequence
	3SDU	Samples placed using at least one standards for both variables.	17.04	extensive use of component
	3SVR	Both verbal responses given in sequence	14.83	moderate component use in required sequence
	3VR	Both verbal responses given	21.62	extensive use of component

Table 45. Summary of Strategy and Strategy Component Transfer Results for Pretests

Task	Score	Score Description	Mean	Extent of Use
Single Var. Classification	2ST-V1	Samples placed by transfer of proximate placement to required standards for 4 sec-counts.	1.21	limited strategy transfer
	2SC-V1	Samples placed by transfer of proximate placements to at least one standard for at least 4 sec-counts.	3.29	limited strategy transfer to one standard
	2SPS-V1	Samples placed by use of required standards	7.21	limited transfer of component in sequence
	2PS-V1	Sample placed by use of at least one standard.	10.00	moderate component transfer

Table 45 (Cont'd.)

Double Var. Classification	3ST	Sample placed by transfer of second task strategy to both variables.	3.00	limited strategy
	3SC	Samples placed by transfer of second task strategy for at least one variable.	6.79	limited strategy transfer of the variable
	3DSS	Sample placed by use of required standards for both variables	5.17	limited transfer of component in sequence on both variables.
	3SS	Sample placed by use of required standards for at least one variable.	12.87	Moderate transfer of component in sequence for one variable
	3DS	Sample placed by use of at least one standard on both variables.	6.70	limited use of component on both variables
	3S	Samples placed by use of at least one standard on one or both variables.	20.37	Extensive use of component on one variable
	3DSVR	Both verbal responses given in sequence.	3.37	Limited use of component in sequence for both variables.
	3SVR	Verbal response given in sequence for at least one variable.	8.29	Moderate use of component in sequence on one variable
	3DVR	Verbal response given for both variables.	11.25	Moderate use of component on both variables
	3VR	Verbal response given for at least one variable.	16.21	Extensive use of component on one variable.

CHAPTER V

CONCLUSIONS AND DISCUSSION

The present study applied an information processing approach to the problem of designing instruction in geology. This approach combines detailed content-task analysis with an information processing view of the learner. Smith (1974) argues the utility of such an approach to effectively improve new learning and especially to enhance transfer of learning. The study had three major goals. The first was to design an instructional sequence which would effectively and efficiently teach fourth grade students to classify igneous rock samples. The second was to evaluate learning and transfer within the sequence. The third was to begin evaluating the selected approach to instructional design.

The design approach used a concept-task-strategy analysis procedure to provide a way of representing the detail and structure of the knowledge related to igneous rock classification. This approach enabled the use of guidelines for the design of instruction suggested by an information processing view of the learner. The application of the design approach provided a three dimensional representation of the knowledge to be learned. The description was in terms of an interrelated set of concepts, task descriptions including the information given to the student and the required performance outcomes, and a cognitive strategy for performing the task using the available information. The information processing view of the learner suggested teaching limited amounts of information during an instructional sequence and sequencing the instructional episodes on the basis of the cognitive strategies.

The thesis of the study was stated in Chapter I as follows:

(1) Instruction for the precursor tasks of a sequence will enhance performance of later tasks when the sequence is designed on the basis of analyzing the structure of the knowledge to be learned and an information processing view of human thinking.

(2) There will be a facilitative effect of instruction based on task specific cognitive strategies within the task sequence.

In particular, the design of instruction as a sequence of tasks which shared common concept and task features was expected to (1) facilitate learning during instruction, and (2) enhance task performance on a posttest, and (3) enhance the transfer of learning to the pretest for a related task. Further, instruction based on task specific cognitive strategies was expected to enhance learning and transfer to an even greater extent within the task sequence.

The central focus on the study was the effect of the strategy based instruction on learning, use, and transfer. The availability of task specific cognitive strategies in the students memory was expected to serve as a mechanism which would enhance learning and transfer.

The premise was that the complete cognitive strategy for a task would be learned during instruction, used during posttest for the same task, and transferred to a new task which shared common concept and task features with the precursor task. For this reason the learning, use, and transfer of the cognitive strategies were carefully described.

Study Overview

The classification of igneous rocks was selected as the knowledge to be taught to the students. The analysis of the knowledge identified the related concepts, described the task, and developed a cognitive strategy by which the task could be performed. The task required students to correctly place a number of rock samples on a given classification scheme.

The Double Variable Classification scheme was formed by two variables which were crossed to form a 3 X 3 matrix defining nine classes of igneous rocks. The two variable names (grain size and the amount of light grains), a label for each row or column (e.g., large grains, about half light grains), and two rock standards for each variable were given on the classification board. The rock standards represented the values which defined each class. (See Figure 4, Chapter 3). The strategy for performing the task consisted of two major components. One was the successive comparisons of a sample to standards to decide the row and column in which the sample was to be placed. The other was a verbal response which was the label associated with each row and column immediately following each decision. An instructional sequence including the

Double Variable Classification Task and two less complex tasks -- a Single Variable Classification and Comparison to standard task -- was designed on the basis of the content, task, strategy analysis. The design also attempted to take into account the limitation of the learner as an information procesor as described by Newell and Simon (1972).

Randomly selected students were assigned to one of three treatment groups. The Cumulative Strategy Group was instructed on the cognitive strategy for each of the three tasks. The Cumulative Feedback Group was given feedback on the correctness of their performance for each of the three tasks. The Isolated Feedback Group consisted of two sets of students one of which was given feedback instruction for the second task only, the other set was given feedback instruction for the final geologic classification task only. Exact instructions as to how to complete the task (i.e., strategy instruction) was not given to either the second or third group. Observations of student behavior were made using specially designed coding systems based on the cognitive strategy models. On the basis of these observations, a number of scores were defined to reflect students' learning, use, and transfer of the strategies during the instruction, the posttests, and the pretests respectively. Additional scores were defined to reflect the accuracy of performance on the pretests and posttests, and the amount of instruction necessary to learn to perform the tasks.

Data analysis (1) described the learning, use, and transfer of the cognitive strategies by students given the strategy based instruction, and (2) evaluated the effects attributable to instruction on the task sequence and those effects attributable to strategy based instruction.

Limitations

There are three major limitations of the validity and generalizability of the conclusions related to this thesis. The first, as with any study, relates to the experimental procedures. The conclusions of any investigation are valid and generalizable only to the extent the procedures described were following and are reproducible by others. The observations of the researcher and limited number of reported problems or errors indicated the procedures were closely followed.

The second is that the conclusions can be directly extended only to the population from which the subjects were sampled. To the extent this population of Lansing, Michigan fourth grade students is representative of students from other populations, the generalizations are valid for those populations. An indicated in Chapter 3, the Lansing School population is representative of a broad range of ethnic backgrounds and three different school settings.

The final limitation is related to the content or the knowledge that is being taught. It would be inconsistent with the epistemologic arguments presented in Chapter 2 to argue that these conclusions are applicable to widely different content domains. However, the results of parallel experiments can be expected to be similar to the extent that (1) the structure of the knowledge in these areas is similar to that under consideration, (2) the learner is accurately represented by the described information processing view, and (3) the design of the instruction correctly relates the knowledge to be learned and the learner.

There is also an important limitation on the interpretation of the results. Little base line data is available with respect to the learning, use, and transfer of cognitive strategies. This resulted in a somewhat arbitrary assignment of criteria on which hypotheses related to strategy performance were supported or rejected. Slightly more or less rigorous criteria could alter portions of the interpretation. The interpretation would be more meaningful if baseline data for strategy learning, use, and transfer in other instructional situations were available.

Conclusions

This section is a summary of the findings of the study. The next section is a discussion of each finding including the implications and questions for future research.

(1) Students were able to learn the task specific cognitive strategies as evidenced by their actions during instruction.

(2) The students encorporated components of the original strategies they had been taught

  (a) in a later performance of the same task on which they had been instructed, and

  (b) in their performance of a new task which was similar to the precursor tasks in several features.

(3) The performance results related to instruction on the task sequence and the strategy based instruction were mixed.

Significant differences occurred at important times during the instructional sequence but did not occur consistently. The differences were generally not dramatic.

(4) The detailed representations of the knowledge the students were to learn in conjunction within an information processing model of human thinking proved useful. The description of the knowledge and the description of limits of the learner as an information processor guided the selection of the content to be included in each instructional episode and the sequencing of the instruction. The detailed representation of the knowledge led to collecting data which provided substantial insight into the manner in which students used and transferred that knowledge.

(5) The experimental design and the thoroughness of the observations generated a very large volume of data which proved difficult and costly to collect, manipulate, and reduce to meaningful scores. Preliminary smaller scale studies could have provided some of the important findings of the study more efficiently.

Discussion

Initial Strategy Learning

The results for the students given the strategy based instruction indicate it is possible to teach task specific cognitive strategies. The strategies for each task were learned within relatively limited amounts of instructional time. All students learned to perform the strategies accurately within three and five trials past the possible minimum of seven for the Comparison to Standard and Single Variable Classification Tasks. Even the larger, more complex strategy for the Double Variable Classification Task was learned well within the twenty-four trials for the first instructional session.

This result indicated the strategies had been learned and implied they would be subsequently available for use by students during their posttest performance of the same task. Furthermore, the implication was that students would have available this knowledge for transfer to the pretest for a new but closely related task.

The results also indicate it is neither difficult or time consuming to teach task specific cognitive strategies. This implies it is reasonable to consider strategies as a type of knowledge to be included in the instruction of students. The value of including strategies as instructional content remains to be answered by results related to performance accuracy.

Strategy Use and Transfer

The students were expected to use the strategy they had been taught for each task when they performed the same task somewhat later. The prediction was that if they had learned a sufficient strategy they would recall and use that strategy. Furthermore, students were expected to transfer the strategy for one task to the next. The tasks shared common features which would allow the performance of the more complex task by the repeated use of the recalled strategy for the previous task.

The students did not use or transfer the strategies to the extent predicted. The use of the complete strategies during the posttests was moderate, and the transfer of the complete strategies to the pretest performance of the next task was very limited.

The rich descriptions of the students' behavior collected on the basis of the strategy models indicated that the learners frequently encorporated components of the original strategies as they developed their own way of performing both the posttests following instruction and the pretest for the next task.*

Partial descriptions of the student performances are possible. The two major components of the strategy were the overt comparison of the samples to the standards and the verbal response indicating the value label on the board for each row or column. Those components were used and transferred either in the sequence as taught or in some other sequence not recognizable as part of the taught strategy. The later type of component use on task posttests was extensive and consistently greater than the moderate occurence of components in sequence.

With respect to the transfer of these same strategy components to a new task, the pattern was identical to that for the use of the strategy

*Note: Only the Single and Double Variable Classification Tasks are considered here. Results related to the Comparison to Standard Task are given in Chapter 4. They are not included as the strategy was not complex enough to yield a variety of performances.

components. That is, the students transferred the components in an invented sequence of their own more frequently than in the sequence which was taught. However, the students were not applying the components as if the tasks could be completed by the repetitive use of strategy components. For example, the transfer of either strategy components, in sequence or not, to both variables of the Double Variable Classification Task was limited. The pattern of component transfer occurred for only one of the two variables.

The strategy use results are parallel to the findings in other studies related to how students use what they have been taught as they perform a task following instruction. After reviewing those studies Resnick suggests the following:

> ". . . most people -- even quite young children -- use environmental feedback to simplify performance routines. They do not accept the routines they are shown as "givens" but rather as starting points. They invent even when we teach them algorithms" (Resnick, 1976, p. 76).

To this can now be added evidence that students use their knowledge of a strategy in a similar manner on transfer tasks which are structurally related to the instructional task.

The findings of this study suggest at least two alternative interpretations. The first is suggested by Resnick's reference to the students use of environmental feedback. It is that students learned the strategies during instruction but only used the strategies and/or components under certain conditions. For example, on the posttests they may be using the strategy on difficult samples only. This would imply a selective or intelligent use of the strategy. Students would be

utilizing the more complex and logically exacting strategy only when a simpler approach was not adequate. A similar hypothesis can be put forth with respect to both the use and the transfer of the strategy components. In performing the Double Variable Classification Task the students may be consistently omitting the application of the strategy or components if they can immediately determine the correct row or column for one variable. As they decide the correct row or column for any one variable they may have eliminated one of the three rows or columns immediately by anticipating the single standard at which the decision will be actually made. These actions would imply the students were constructing a strategy which was more efficient. The possibility of students constructing such abbreviated strategies was suggested by the observation that students often expressed frustration at having to complete the whole strategy when they "didn't need to use it all."

The second alternative is suggested by the information processing view that students can rehearse information in short term memory without storing that information in long term memory. The supposition would be that students did not actually learn the complete strategies during instruction but instead (1) learned the components and (2) with the help of repeated instructional cues rehearsed the sequence in which they were to be executed. During the delay between instruction and posttest, the sequence would have been forgotten. Upon confronting the identical task the students may have constructed a new although not necessarily different sequence for using the strategy components. During the performance of the next more complex task the students may have created sequences for using the strategy components which would reflect the sequence of component use only for that portion of the new task which was nearly identical to the previous task (e.g., the transfer of the comparison-to-standard component from the Single Variable Classification Task to only one variable of the Double Variable Task). This interpretation is more tenuous than the first in light of the studies cited by Resnick (1976, p. 68) and the strategy learning data from this study. However, it is plausible and should be considered.

In either case a series of strategy models inferred from student actions are needed to describe in greater detail how students were modifying the strategies they had been taught. Additional analysis of data from the present study could provide substantially more complete descriptions of the students' learning, use, and transfer of the strategy components in two ways. One description would relate the use and transfer of components to the accuracy of sample placement. A second would identify the particular circumstances under which the strategy and strategy components were used and transferred. For example on the final task were the components utilized for one of the two variables, for difficult samples, or at the immediate point in their thinking when a row/column decision was being made.

Knowing in some detail what information the students initially learned and then utilized following instruction could contribute substantially to the instructional design. Instructional sequences based on task specific cognitive strategies may be more efficient and effective if the strategies generated by the students served as the basis for developing and sequencing tasks. Those strategies may be small, simple, and based on conditional statements related to particular circumstances within the task.

Instructional sequences of this type would have to be tested against sequences based on a more "complete" strategy. Teaching the more elaborate, complex strategies such as those used in the present research may help the students comprehend the task and the function of the components in a way not accomplished by teaching the smaller strategies.

Performance Results

A third major finding of the study has to do with the effects of the instruction on the learners' performance of the classification tasks. The central research predictions were: (1) students would efficiently learn to classify igneous rock samples accurately if instructed on a sequence of tasks which shared common concept, task, and strategy elements, and (2) the effect of teaching cognitive strategies for each task would be even more effective in improving performance.

The performance results were mixed but interesting. The predicted effects of instruction on the task sequence and the added effects of the strategy based instruction were not observed at all until the final Double Variable Classification Task. The effects attributable to instruction on the task sequence were observed in the pretest and during instruction for the Double Variable Classification Task. The effects of the strategy based instruction were observed only on the posttest.

The accuracy with which the students who were instructed on the entire sequence performed the pretest and the ease with which they learned to perform the task was significantly better than for those students who were given feedback instruction on the final task only. The students instructed on the sequence correctly classified 52% (4) more samples and were placing 54% of the samples correctly on the pretest. The difference is statistically significant while the level of performance is moderate. The same students learned to perform the task in 29% (6.5 samples) fewer trials than did students instructed on the final task only. The difference is again significant and in absolute terms is substantial. There were no effects attributable to the strategy based instruction within the sequence during the pretest or instruction on the Double Variable Classification Task.

The pattern of results was different for the posttest on the final task. Feedback instruction on the sequence was not effective, while the strategy based instruction within the sequence was effective. The Isolated Feedback group learned to perform the task as well as the Cumulative Feedback Group which was given instruction on the entire task sequence. The groups correctly placed 58% of the samples (13.83 and 13.79 samples respectively). The improvement of the Isolated Feedback group from pretest and posttest was substantial (63% or 5.33 samples). The Cumulative Strategy Group performed the task significantly better than either the Cumulative or Isolated Feedback groups. The students given the strategy based instruction performed the task approximately 18% (2.45 samples) better than the other groups. The accuracy of their placement was 68% (16.25 samples). While the differences were significant and percentage differences substantial, the results are not dramatic in absolute terms.

The findings are substantial enough to continue research under the present design approach. The differences in performance which were evident did occur at the important point in the instructional sequence, that is, during the students performance of geologic classification task. The strategy based instruction did result in superior final performance. These differences were not likely to have occurred by chance. However, the findings were not consistent across tasks or even within the pre-test, instruction, posttest cycle for the final task. In addition, the absolute differences were not dramatic. These two points would argue against beginning the design of instructional sequences which were based on the present approach on any substantial scale without further research.

The most promising avenue of research would be on the effects of strategy based instruction for longer sequences of more complex tasks. This is suggested by (1) the occurence of all effects on the final most complex task, (2) the late emergence of effects related to cumulative strategy based instruction. If there is a cumulative strategy effect, modest differences could develop into very important and large differences over a longer sequence of more complex instruction.

There are several research questions directly related to the line of research suggested above.

(1) What effects would occur by changing the present sequence of tasks? For example, would instruction on only one of

the precursor tasks affect student performance? Would strategy based instruction for the Double Variable Classification Task only result in performance as accurate as that exhibited by students given strategy based instruction throughout the sequence?

(2) Are the various instructional effects related to the complexity of the tasks? The effects observed during this study occurred only during the most complex task. It is quite possible that the effects of strategy based instruction will only be evident when relatively complex performance is required.

(3) Will the effects attributable to instruction on similarly designed instructional, sequences and strategy based instruction within the sequence change across the pretest, instruction, posttest cycle as they did in the present study? The answer may contribute to understanding when the effects of a particular type of instruction can be expected to occur.

(4) What are the long term effects of the present instructional design or a modified version of that design? The effects of the instruction on the task sequence and strategy based instruction may be more or less dramatic than is indicated in the present study.

Representation of the Content of Instruction

Central to the present design approach was the representation of the knowledge the students needed to learn. This guided the design of the research and led to detailed descriptions of student behavior. These descriptions provided substantial insight into the manner in which students used and transferred the knowledge they had been taught.

The attempt was to provide a theory of what the students should know to classify igneous rocks. The discipline (geology) served as an important source for identifying this knowledge. The knowledge (or inner environment) of the learner was viewed as composed of an inter-related set of concepts and a cognitive strategy which utilized the concepts as inputs and outputs. In information processing terms, the concepts and strategy constituted the information necessary and sufficient to meet the requirements of the external task environment. Effective performance was expected to the extent that the learner's knowledge was appropriate for that task environment. The descriptions of the task requirements and the theory of the sufficient knowledge were gained by applying the content-task-strategy analysis (Smith, 1974) and the information processing view of human thinking (Newell and Simon, 1972).

The importance of having a detailed description of the desired learners' knowledge is best demonstrated by considering the role the strategy model(s) played in designing the instructional sequence and research procedures. The example also illustrates important guidelines the information processing view provided the present approach to design.

The strategy for the Double Variable Classification was based on the notion that geologists used mental models or standards when classifying rock samples. The final strategy was designed knowing what concepts would be available as information to be processed and the required outcome. This made possible the description of a strategy sufficient for classifying the rock samples.

The information processing view indicated that human information processing is basically serial in nature and that only a very limited amount of information could be held in short term memory. This necessitated a strategy which used information output from one process as input for the next process as much as possible. Otherwise, important information could have been forgotten, over the course of executing the strategy.

The rather lengthy and complex strategy which resulted represented part of the knowledge sufficient to perform the classification task. The relatively long times required for storing information in long term memory indicated that to teach the strategy all at once would be very demanding on the students memory. Smith's work suggested that strategies for less complex tasks could become subroutines in larger strategies and serve to reduce the memory load since the details of the subroutines would have been already learned as a units or "chunks." Given the detailed description of the strategy for the final task, it was possible to identify potential subroutines. Precursor tasks were selected and sequenced in part because they could be performed using these compatible subroutines.

The strategy model for each of the three tasks in turn guided the development of instructional protocols to teach the strategies. The models were the basis for the system of collecting raw data and translating that data into meaningful scores which would adequately and accurately represent the students' use and transfer of the strategies. The models insured that relevant behavioral data were collected. These data were useful in inferring use of components of the strategy as well as use of the entire strategy or originally planned.

The methodology of the study became in large part a matter of translating the strategy models into protocols, a data collection system, and a set of meaningful scores. The resulting description of the students' learning, use, and transfer of the strategies provided a very rich description of student behavior.

Theories of a student's knowledge such as the strategy models of this study are useful in instructional design and research. With a detailed task specific representation of students' knowledge as a frame of reference it becomes possible to predict specific student behaviors and collect extensive empirical evidence to test the predictions. If the predictions are not supported, the rich descriptions of behavior make available new knowledge about the students thinking. This knowledge can serve as the basis for alternative predictions to be used in research and the design of other instructional sequences. In fact, many of the alternative predictions, future research questions, and alternative proposed instructional sequences stated throughout this chapter were possible only because rich descriptions were available. They would not have been possible if the only available information was related to performance accuracy and trials to criterion scores. The substantial benefits of gaining a representation of the content or knowledge to be taught in terms of concepts, task requirements, and strategies in the instructional design and research has been argued above. However, one caveat is necessary. Such analysis was not simple and straight forward to accomplish for two reasons. First, it was initially difficult to understand and to apply Smith's analytic constructs in the analysis of the content. Second, the time required to produce such an analysis is substantial as the product is a large number of highly interrelated pieces. While these difficulties should be anticipated, anyone attempting such analysis should not be deterred as the benefits appear to outweigh the costs.

The Efficiency of a Large Scale Experimental Study

The final finding is related to the benefits, cost, and efficiency of conducting a large scale experimental study such as this one.

A study of this magnitude has the advantage of providing information related to the effectiveness of the instruction and the detailed description of student performance at the same time. Without a study of this scale it would have been impossible to assess the effects attributable to instruction on the task sequence and the strategy based instruction within the sequence. However, the experimental design required a large number of trained personnel (approximately 20), several supporting people, and daily contact with seventy-two students for over three weeks. The thoroughness of the observations generated a very large volume of data which proved difficult and costly to collect, manipulate, and reduce to meaningful scores.

The large scale experimental study is probably not an efficient way to proceed without the benefit of preliminary, more intensive, small scale studies. Smaller studies could have provided the same strategy performance information, guidance in the development of the instructional sequence, and baseline information to be considered in the interpretation of the results. Two types of studies are suggested.

The first is intensive study of a few individuals given strategy based instruction across tasks. This would probably have revealed that students were not using and transferring the complete strategies. Such information would have modified this central premise of the present study. With fewer subjects it would have been possible to use the process tracing techniques to establish more complete models of their strategy performance. This additional step would have provided the detailed descriptions of the students' strategies which must now be sought post hoc from data obtained at a high cost. It would have been possible to establish if students were reformulating what they had been taught into one of a limited number of strategies, if strategies (or components) were being used under identifiable circumstances, or if the strategies were entirely idiosyncratic. Models of their thinking could have been used to modify the initial strategy or develop an alternative more compatible with the students' inclinations. This then could have become the basis for the design to be examined with a large scale experimental study.

A second type of small scale study is also needed.

Baseline studies would have provided information useful in the instructional design and in guiding the research procedures. Baseline data on task difficulty for uninstructed students could have provided standards against which to gauge the effects of two types of instruction and within each type of instruction the effectiveness of alternative instructional protocols. Baseline studies on strategy use and transfer could also have helped established as somewhat less arbitrary assignment of criteria on which hypotheses related to strategy performance were accepted or rejected.

An additional benefit of both types of studies would be the opportunity to develop on a small scale protocols, scoring procedures, and programs for the analysis of the scores. The insight gained from the smaller studies would have assured the collection of the necessary and sufficient data during the larger study. Furthermore, the availability and use of limited sets of representative data in developing both scores and analysis procedures would have been more cost effective.

Summary

The following (Table 46) is a summary of the conclusions, implications and questions derived from this study.

Table 46. Summary of Conclusions Implications and Questions for Future Research

Conclusion	Implications and Questions
Strategy Learning	
--Students were able to learn task specific cognitive strategies in a reasonable amount of instructional time.	--Task specific cognitive strategies can be reasonably considered as a type of knowledge to be included in the instruction of students.
Strategy Use and Transfer	
--Students incorporated components of the strategies they were taught during instruction on the task posttests and in their pretest performance of a new but similar task.	--Did the students initially learn the complete strategy or were they learning components and rehearsing the sequence in which components were to be used? --Did students learn the strategies during instruction but apply components under particular circumstances such as encountering a difficult sample? --Would instructional sequences based on task specific cognitive strategies be more efficient and effective if the strategies generated by students served as the basis for developing and sequencing tasks?

Conclusion	Implications and Question
Task Performance	
--The performance results related to instruction on the task sequence and strategy based instruction were mixed.	--The treatment effects were substantial enough to warrant additional research, but insufficient to argue for using the present instructional design approach on a large scale.
--Statistical significant differences were generally not dramatic.	--The most promising avenue of research would be on the effects of strategy based instruction for longer sequences of more complex tasks.
--All effects were observed on the Double Variable Classification Task.	--What effects would occur by changing the present sequence of tasks? In particular, how accurately would students given strategy based instruction for the Double Variable Classification Task only be able to perform the final pretest?
--Instruction on the task sequence (a) enhanced the transfer of learning to the pretest and (b) facilitated learning during instruction on the Double Variable Classification Task.	--Are the various instructional treatment effects related to the complexity of the tasks?
--Students given outcome feedback instruction for the final task only performed the post-test as accurately as students given feed-back instruction for the entire task sequence.	

Conclusions	Implications and Questions
--The ability of students given strategy based instruction to perform the Double Variable Classification on the posttest was better than for either of the feedback groups.	--Will the variable effects of the instructional treatments change across the pretest, instruction, posttest cycle for other similarly designed instructional sequences?
	--What are the long term effects of the present instructional design or a modified version of that design?
<u>Representation of Context of Instruction</u>	
--The detailed representation of the knowledge to be taught in terms of Smith's concepts, tasks, and strategies and with an information processing view of the learner was complex, but very useful.	--A detailed description of the knowledge necessary and sufficient for students to be competent in a particular content domain is useful in predicting specific student behaviors, testing those predictions, and generating alternative predictions.
--The approach guided the design of the research and lead to detailed descriptions of student behavior.	
--The descriptions provided substantial insight into the manner in which students used and transferred the strategies they had been taught.	

Conclusions	Implications and Questions
Efficiency of a Large Scale Experimental Study	
--The experimental design and the thoroughness of the observations generated a very large volume of data which proved difficult and costly to collect, manipulate, and reduce to meaningful scores.	--Preliminary smaller scale studies would have provided (1) the instructional protocols, scoring procedures, and data analysis procedures and (2) some of the important findings of this study more efficiently than the large experimental study.

APPENDICES

APPENDIX A

DEFINITIONS OF PRIMARY PROCESSES

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DEFINITIONS OF PRIMARY PROCESSES

The primary processes used in the development of the model cognitive strategies are completely described below.

ACT

"This is the process of acting on an object in such a manner as to obtain a particular kind of input (e.g., color or temperature information). This might involve orientation of the required organs, exploratory movements such as visual scanning or tactile exploration, and/or manipulation of objects such as hefting or squeezing. Performance of ACT requires a prior retrieval of the appropriate action from long-term memory, i.e., activation of the observation action node in an associative network. This activation makes available the information from which a control program can be reconstructed. For present purposes, no distinction will be made between the construction and execution of the program and ACT will be treated as a primary process. It may eventually prove necessary or useful to break it down further. The input for ACT includes the observation action concept and the differentiated object on which the action is to be performed. The output is the resulting input to the individual. Analysis of the input is carried out by other processes." (Smith, 1972, p. 153).

CHOOSE 1

"CHOOSE 1 is a primary process similar to CHOOSE in nature, but differing from CHOOSE in that some criterion is used for the choice.

CHOOSE implies a certain randomness of choice, or at least a choice based on such non-salient factors as proximity to the chooser or visual accessibility. CHOOSE 1 implies a choice which is non-random, which is based on some salient criterion CHOOSE 1 might compare a value for one element which is encoded and stored in short term memory to a series of perceived values of elements and choose the one element from the series which best approximates the value of that one element. In this case CHOOSE 1 has provided an approximation of the value of the original element." (Padilla, 1975, p. 204).

COMPARE

"This primary process determines the comparability of two encoded units of information, e.g., encodings of texture information for two objects. COMPARE essentially monitors the node or nodes activated as a result of the encodings. If the same node is activated on both occasions, a judgment of comparability is made. If different nodes are activated, a judgment of non-comparability is made. The output of COMPARE can itself be viewed as the activation of a node in a network. This network includes nodes corresponding to the concepts "same" and "different" (and perhaps others). The activation of one of these nodes makes immediately available certain operational alternatives including verbal output. The particular alternative to be executed, if any, is determined by some controlling mechanism which represents the strategy being employed by the individual." (Smith, 1972, p. 155).

DECODE

"This is the primary process by which an associative network is entered by way of a verbal label for one of the constituent concepts. The input for the process is the verbal label. Decoding of the label results in the activation of a concept or node in the network. This does not necessarily result in the reconstruction of images, actions, or verbal entities. In effect, the DECODE process opens the way to many possibilities, but it remains for the next step(s) to take advantage of one or more of them. The possibility that the individual is set to perform another step which then follows automatically from the decoding need not concern us here. The point is that access to the storage network must be gained as a result of processing the verbal label. This is the function of the DECODE process." (Smith, 1972, p. 150).

ENCODE

"This primary process analyzes the detail information which has been attended to, e.g., as a result of SELECT. The general nature of the information has already been determined (note the nature of ACT and SELECT) and it remains for ENCODE to make a determination about this specific case. For example, ENCODE might be preset to analyze texture information. ACT and SELECT has made such information available. ENCODE determines whether or not the texture information is novel and, if not, categorizes it in some manner based on previously experienced texture information. If the information is novel, a new category is created. Thus, ENCODE involves long-term memory. In terms of an associative network, the analysis of texture information activates a node representing a texture value concept or else forms a new node paralleling other texture value nodes. The input for ENCODE is selected non-verbal sensory information. The output is a value concept (the activation of a node). Undoubtedly, some additional contextual information about the experience will enter short-term memory. Some may also enter long-term memory." (Smith, 1972, p. 154).

LOCATE

This primary process involves the search for a position logically or spatially related to a particular source of information in the environment. The input to the process may be another position, object, or verbal label.

ORDER

"This is a primary process which attends to and assesses the magnitudes of two differing encoded units of information. ORDER sequentially evaluates the two magnitudes and then hierarchically orders them from lesser to greater. This primary process then basically monitors the nodes activated as a result of the encodings. The COMPARE secondary process usually precedes and determines whether or not different nodes were activated during encoding. If this results in a judgment of non-comparability, it is the function of ORDER to evaluate the two nodes successively and to seriate them appropriately. The output of ORDER can itself be viewed as an ordinal concept, i.e., the activation of a node in a network. This network includes nodes corresponding to the concept of "more" and "less" (and perhaps others). The activation of one of these nodes makes immediately available certain operational alternatives including verbal output and appropriate serial positioning of the elements. The particular alternative to be executed, if any, is determined by some controlling mechanism which represents the strategy being employed by the individual." (Smith, 1972, p. 156).

<u>PLACE</u>

"This primary process involves a spatial placement of an element to indicate its membership in a set. The criterion for placement is unspecified in the process itself although it will usually be retained in short-term memory from earlier steps. The input to the set is an element currently attended to and an affirmative result from the application of the criterion for set membership. The output is the element in its new spatial location. A variety of contextual information placed in short-term memory usually enables the individual to recognize the subset previously set aside by PLACE." (Smith, 1972, p. 153).

<u>REPORT</u>

"This is the process by which verbal responses are made. The input is a concept. The output is a verbal label for the concept embedded in an appropriate linguistic context (not necessarily a complete or correct sentence)." (Smith, 1972, p. 157).

<u>SCAN</u>

"This is a primary process which represents a rather cursory, largely visual, exploration of the stimulus field. It establishes a figure-ground differentiation of objects and detects a few salient features which may enter short-term store. However, only partial information is obtained, even in the visual modality. Detection of certain salient and/or relevant features usually terminates the SCAN process, or at least relegates it to a background role, and triggers some attentive processing. Thus, the input to SCAN is undifferentiated stimulus information while the output is one or more differentiated perceptual objects. In most cases, many features which are relevant from a formal point-of-view are not detected by SCAN." (Smith, 1972, p. 152).

SELECT

"This is a primary process which sorts relevant information from irrelevant. In particular, it filters out almost all information except for that for the variable (or variables) judged relevant to the task at hand. Thus, the input is undifferentiated input and the variable concept. The output is information on the relevant variable about the perceived object. Actually, the process is not simply a next step following complete execution of ACT. Rather, along with ACT it forms an active system with a feedback capability which allows modification of the detailed functioning of ACT until the appropriate input has been made available. This represents a monitoring function of SELECT. Such feedback mechanisms are probably involved in many primary processes. The large number makes it cumbersome to make them all explicit in the task routine. This aspect of the primary process is probably important to keep in mind, however." (Smith, 1972, p. 153).

APPENDIX B

MULTIPLE CLASSIFICATION MATERIALS AND PROCEDURE

APPENDIX B

MULTIPLE CLASSIFICATION MATERIALS AND PROCEDURE

The multiple classification pre-test administered to all students was developed by Bridgham (1967). The test consisted of eight cards. Each card presented a vertical row and a horizontal row of geometric pieces which intersected in a blank space. All the pieces in one row shared one or two class properties (color, shape, size). The pieces in the other row shared a different class property. Also on each card was a separate group of alternative figures which could be placed at the blank intersection. The correct alternative had the property common to all pieces of the horizontal row and the property common to all pieces of the horizontal. Students were asked to select the correct piece from the alternatives.

The procedure is given below as stated by Bridgham. The only change was to omit the line which is given in parentheses.

> Show first card. Here are two groups of things. Point. You can see there's a space here where something is missing. Point. Down here are some things which might go in the space. Point. Which of these things do you think should go in this space? Record choice. (Why did you pick that one.) If S changes his mind, record the second choice, third choice, etc. Score on the basis of the last choice.
>
> Show next card. Here are two more groups of things. Point. Which of these things (point) should go in this space? Point. Record choice as above. (Why did you pick that one?) Repeat this procedure for all succeeding cards.

The cards and pieces were made from poster board. The cards were white and 16 inches square. The shapes of the various pieces are shown in Figure 20 for the large (1-1/2 inch) and small (2-1/2 inch) sizes. The arrangement, color, shape, and size of each card is listed below. The descriptions are identical to those given by Bridgham (1967). The alternative pieces were separated from the rows by 1/4" black poster tape.

<u>Card 1</u>	(All pieces small)
Horizontal row:	yellow pieces--triangle, square, ring, circle, blank
Vertical row:	blank; rectangles--red, blue, black white
Alternatives:	yellow circle, red rectangle, green triangle, yellow ring segment, yellow triangle*.
<u>Card 2</u>	(All pieces red)
Horizontal row:	squares--1 inch; 3 inch; 2 inch; 2-1/2 inch; blank
Vertical row:	1-1/2 inch pieces--rectangle, ring segment; blank; circle; triangle.
Alternatives:	1-1/2 inch square*, 2-1/2 inch square, 1-1/2 inch circle, 1-1/2 inch ring segment, 2 inch ring.
<u>Card 3</u>	(All triangles)
Horizontal row:	green triangles--1-1/2 inch, 2 inch, 1 inch, 3-1/2 inch; blank
Vertical row:	blank; 2-1/2 inch triangles--red, white, blue, black
Alternatives:	blue 3 inch triangle, green 3-1/2 inch triangle, blue 1 inch triangle, red 2-1/2 inch triangle, green 2-1/2 inch triangle*.
<u>Card 4</u>	(All large pieces)
Horizontal row:	circles--orange, white, red, yellow; blank
Vertical row:	blank; blue pieces--triangle, triangle, ring segment, square
Alternatives:	blue rectangle, orange square, blue circle*, yellow circle, yellow rectangle.

Card 5	(All squares)
Horizontal row:	1-1/2 squares--yellow, blue, white, green; blank.
Vertical row:	red squares--4 inch, 1 inch, 3 inch, 2 inch; blank
Alternatives:	1-1/2 inch blue square, 1-1/2 inch green square, 1-1/2 inch red square*, 2 inch red square, 3 inch blue square.

Card 6	
Horizontal row:	green piences--2 inch circle, 2-1/2 inch ring segment, 1-1/2 inch square, 2-1/2 inch triangle.
Vertical row:	1-1/2 inch rectangles--blue; blank; yellow, orange, red.
Alternatives:	blue 1-1/2 inch rectangle, green 2-1/2 inch ring segment, blue 2-1/2 inch triangle, green 2-1/2 inch rectangle, green 1-1/2 inch rectangle*, red 2 inch circle, yellow 1-1/2 inch rectangle.

Card 7	
Horizontal row:	ring segments--yellow 3-1/2 inch, white 2-1/2 inch, green 3 inch, red 1-1/2 inch; blank.
Vertical row:	2-1/2 inch orange pieces--circle, triangle, square, blank; ring
Alternatives:	green 2-1/2 inch square, yellow 2-1/2 inch triangle, orange 2-1/2 inch ring, white 3-1/2 inch ring segment, red 1-1/2 inch ring segment, orange 2-1/2 inch segment*.

Card 8	
Horizontal row:	blue circles--2-1/2 inch, 1 inch, 3-1/2 inch; blank; 3 inch.
Vertical row:	1-1/2 inch pieces--green square, black ring segment, red rectangle, yellow triangles; blank.
Alternatives:	blue 3 inch circle, green 2-1/2 inch triangle, blue 1-1/2 inch circle*, blue 3-1/2 inch circle, yellow 1-1/2 inch triangle, green 1-1/2 inch rectangle, white 2 inch ring segment.

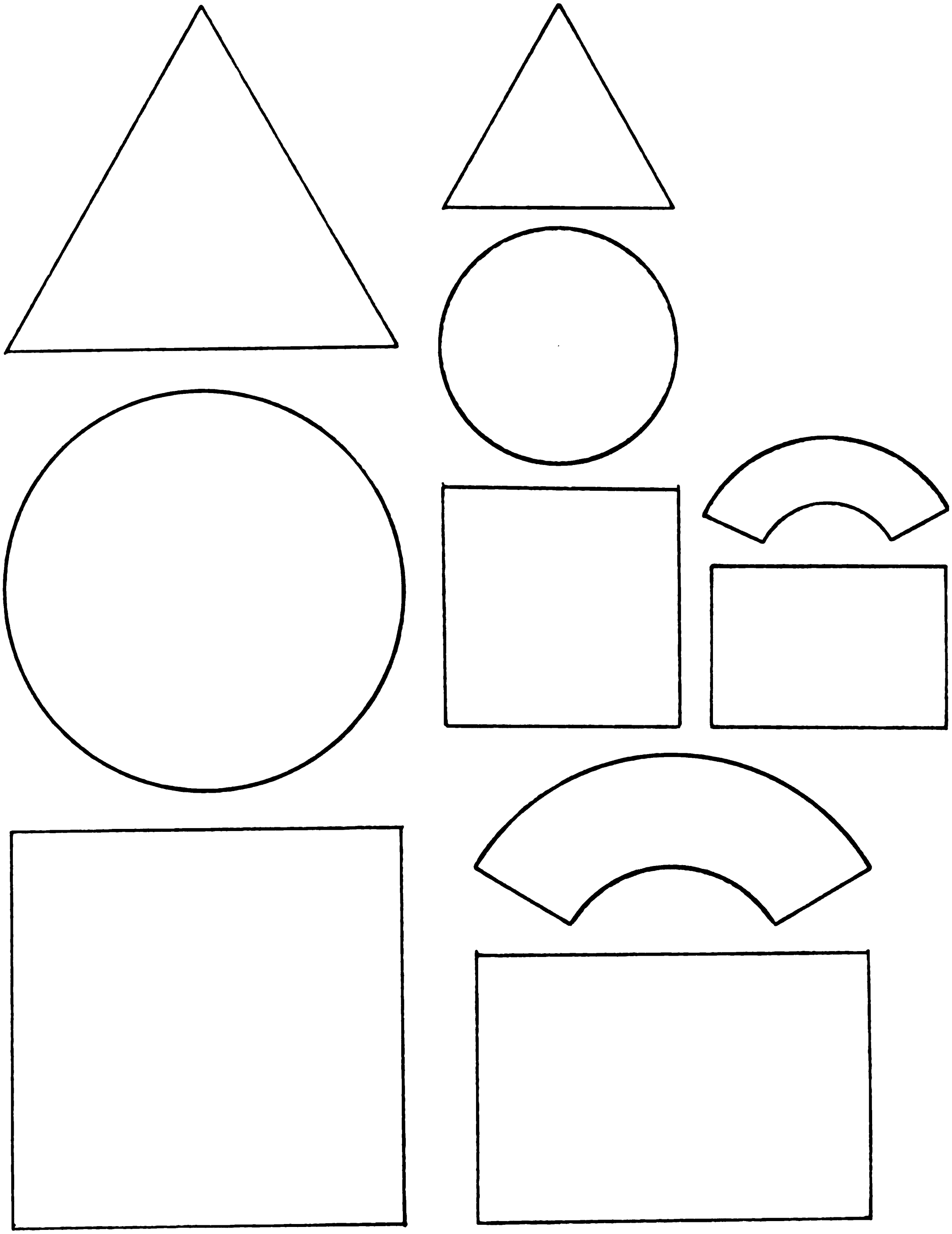

Figure 20. Large and Small Shapes for
Multiple Classification Pieces

APPENDIX C

INSTRUCTIONAL PROTOCOLS

APPENDIX C

INSTRUCTIONAL PROTOCOLS

The following pages are the complete protocols used during the research. Protocols for the instruction on systemic concepts, comparison to standard task, Single Variable Classification Task and Double Variable Classification Task are included. For the first two tasks there are two sets of protocols, one for the variable grain size, the other for the variable amount of light colored grains.

The first of these protocols is related to the systemic instruction. Before instruction on any task, all students were taught to identify mineral grains, variable names related to grains size (large grains, small grains, glassy rocks) and the variable names related to the amount of light grains (mostly light grains, about half light grains, mostly dark grains). Instructors pointed to examples and asked student to identify additional examples for each concept.

The remaining protocols were read by instructors as they explained and demonstrated the task. The protocol for each task consisted of the general task instructions and strategy or outcome feedback instructions. The general task instructions were given to all students as pre-test and post-test instructions. The strategy or outcome feedback instructions were given immediately following the pre-test depending on the treatment to which the student had been assigned. Both the strategy and outcome feedback instructions were composed of initial instructions and error responses to be made by the instructors for various types of errors.

(Note: Be sure to point to the outline of each grain as you demonstrate. Have the students do the same if you have any doubt of their understanding.)

Systemic Instruction

--Before I have you start the task, there are some things I want you to learn about rocks.

--Rocks are made up of grains. Look at these rocks and I'll show you what a grain is. I'll also show you about the size and color of the grain.

Sample A --This rock has large grains.

--This is a grain (point) (Repeat for three grains). Can you show me three of the large grains in the rock? Good! This rock has large grains.

Sample B --This rock has small grains.

--This is a grain (point) (Repeat for three grains) Can you show me three grains in this rock? Good! This rock has small grains.

Sample C --The grains in this rock are so small you just see them. Each of these small sparkles is a grain. This is a small grain (Repeat for three grains). Can you show me three small grains in the rock? Good! This rock has small grains.

Sample D --In rocks like these the grains are so small that you can't even see them. When the whole rock is made of grains this small we call them rock glassy.

--When do we call a rock glassy? (Student response.)

--I also want you to learn what is a light grain and what is a dark grain.

Sample A --This rock has mostly light colored grains. Only the grains that are black are called dark grains.

--Even the grey grains like this (point) are light grains.

--Is this (point) a light or dark grain? (Repeat for several light and dark grains. Include a grey grain)

--Good! This rock has mostly light grains.

Sample B --This rock has about half light and half dark grains.

--Is this (point) a light or dark grain? (Repeat for several light and dark grains)

--Good! This rock has about half light and half dark grains.

Sample C --This rock has mostly dark grains. Each of these small sparkles is a grain.

--Can you show me three dark grains?

--Good! This rock has mostly dark grains.

Note: Understanding by the student is critical. If you must continue to be assured of their understanding, do so by repeating relevant portions of protocol before going on.

COMPARISON TO STANDARD

Pretest and General Task Instructions   Amount of Light Colored Grains

--For this task, I want you to look at the amount of light colored grains. Remember only the grains that are black are dark grains. All other grains are light grains.

Example A--Remember, these are light grains (point to 3)
and these are dark grains (point to 3)

--This rock is a standard (point). I want you to look at the amount of light colored grains in the standard and in the rock I hand you.

--First, tell me if each rock I hand you has more light grains, the same amount of light grains, or more dark grains than the standard.

--Then, place the rock in the square where it belongs. (point to squares)

--The rocks with more light grains or the same amount of light grains as the standard go here (point to square).

--The rocks with more dark grains than the standard go here (point to square 2).

--(Pause)

--Remember, tell me if each rock I hand you has more light grains, the same amount of light grains, or more dark grains than the standard.

--Then, place the rock in the square where it belongs.

INSTRUCTOR NOTE: If this is the pretest instruction for the second variable for this student, use the following.

--Remember, what you learned last time. I want you to use what you have learned to do this, but be sure you use the amount of light colored grains.

--Do you have any questions about what I want you to do?

COMPARISON TO STANDARD

Strategy Instruction — Amount of Light Colored Grains

--I want you to do this again with some new rocks. Remember to look at the amount of light colored grains. Tell me if the rock I hand you has more light grains, the same amount of light grains, or more dark grains than the standard. Then, place the rock where it belongs.

--Before you begin, I want to show you a way to do this.

--First, remember what a light grain is and what a dark grain is.

--Then, move the rock very close to the standard. (point to standard) Take some time to look back and forth between the rock and the standard several times.

--After you have checked carefully, tell me about the amount of light colored grains the rock has.

--Next, look at the labels on the board (point to labels) to find the correct square.

--Then place the rock where it belongs.

DEMONSTRATION DIALOGUE (Use examples A and C)

--Watch while I demonstrate this for you.

Example A:

--First, remember what a light grain is and what a dark grain is.

--Move the rock very close to the standard (move rock).

--Take some time to look back and forth between the rock and the standard several times (point back and forth).

--Then, tell me whether the rock has more light grains, the same amount of light grains, or more dark grains than the standard. This rock has more light grains than the standard.

--Then look at the labels on the board to find the correct square. This rock has lighter grains than the standard (point to "lighter") so it goes in this square (place in square 1). If a rock has the same amount of light grains as the standard, I would also place it here.

COMPARISON TO STANDARD

Strategy Instruction (Continued) Amount of Light Colored Grains

Example C:

--Here is another example.

--First, remember what a light grain is.

--Move the rock very close to the standard (move rock). Take some time to look back and forth between the rock and the standard (point back and forth).

--Then tell me about the amount of light colored grains. This rock has more dark grains than the standard.

--Then look at the labels on the board. This rock has more dark grains than the standard (point to "more dark") so it goes in this square (place in square 2).

--Do you have any questions about what I want you to do?

COMPARISON TO STANDARD

Strategy Instruction — Amount of Light Colored Grains

Strategy Error Responses

A correct trial must include all of the following:

(1) The rock is proximate to the standard.
(2) The verbal response is correct.
(3) The placement is correct

FOR CORRECT TRIAL:

1. (If proximate, correct verbal response and placement)

Good! This rock has more light grains/the same amount of light grains/more dark grains than the standard and was put here (point).

FOR ERRORS:

II. (If not proximate, correct verbal response)

Good! This rock has more light grains/the same amount of light grains/more dark grains than the standard and was placed here (point). But you forgot to put the rock next to the standard. Be sure you do this (move rock to standard). Take time to look back and forth carefully several times (point back and forth) before you tell me about the rock, and put it in a square.

III. (If not proximate, incorrect verbal response)

No! This rock has more light grains/the same amount of light grains/more dark grains than the standard. You forgot to put the rock next to standard. Be sure you do this. (move rock to standard). Take time to look back and forth carefully several times (point back and forth) before you tell me about the rock, and put it in a square.

COMPARISON TO STANDARD

Strategy Instructions (Continued) Amount of Light Colored Grains

Strategy Error Responses

IV. (If proximate and incorrect verbal response)

No! This rock has more light grains/the same amount of light grains/more dark grains than the standard and should be put here (point). Be sure you take time to look back and forth carefully several times (point back and forth) before you tell me about the rock, and put it in a square.

V. (If proximate, correct verbal response, incorrect placement)

You told me about the size of the grains correctly but you put it in the wrong square. It should have been placed here (point). Be sure you look at the labels (point) before you put the rock in a square.

Note: After 4 incorrect trials in a row repeat demonstration with Example A.

COMPARISON TO STANDARD

Feedback Instruction   Amount of Light Colored Grains

--I want you to do this again. Be sure you look at the amount of light colored grains. Tell me if the rock I hand you has more light grains, the same amount of light grains, or more dark grains than the standard. Then place the rock where it belongs.

--This time I will tell you if you are right or wrong for each rock I hand you.

Example A:

--Here is an example. (Place Example A in Square 1)

--This rock has more light grains than the standard. It goes in this square (point). If a rock has the same amount of light grains as the standard, it would also go in this square.

Example C:

--Here is another example (Place Example C in Square 2)

--This rock has more dark grains than the standard. It goes in this square (point).

--Do you have any questions about what I want you to do?

COMPARISON TO STANDARD

Feedback Error Responses: Amount of Light Colored Grains

A correct trial must include both of the following:

(1) correct verbal response.
(2) correct placement.

FOR CORRECT TRIAL:

I. (If correct verbal response and placement)

Good! This rock has more light grains/the same amount of light grains/more dark grains than the standard and was put here (point).

FOR ERRORS:

II. (If correct verbal response and incorrect placement)

You told me about the size of the grains correctly but you put it in the wrong square. It should have been placed here (point).

III. If incorrect verbal response

No! This rock has more light grains/the same amount of light grains/more dark grains than the standard and should be put here (point).

Note: After 4 incorrect trials in a row repeat demonstration with Example A and C.

COMPARISON TO STANDARD

Pretest and General Task Instruction   Grain Size

--For this task, I want you to look at the size of the grains.

Example A--This rock has large grains (point to 3)

Example B--This rock has small grains (point to 3)

Example C--This rock has small grains, too (point to 3)

Example D--This rock is glassy because the grains are too small to see.

--This rock is a standard (point). I want you to look at the size of the grains in the standard and the rock I hand you.

--First, tell me if each rock I hand you has larger grains, the same size grains or smaller grains than the standard.

--Then, place the rock in the square where it belongs (point to squares).

--The rocks with larger grains or the same size grains as the standard go here (point to square 1).

--The rocks with smaller grains than the standard go here (point to square 2)

--(Pause)

--Remember, tell me if each rock I hand you has larger grains, the same size grains or smaller grains than the standard.

--Then, place the rock in the square where it belongs.

Instructor Note: If this is the pretest instruction for the second variable for the student, use the following!

--Remember what you learned last time. I want you to use what you have learned to do this, but be sure you use the size of the grains.

--Do you have any questions about what I want you to do?

COMPARISON TO STANDARD

Strategy Instructions | Grain Size

--I want you to do this again with some new rocks. Remember to look at the size of the grains. Tell me if the rock I hand you has larger grains, the same size grains, or smaller grains than the standard. Then, place the rock where it belongs.

--Before you begin, I want to show you a way to do this.

--First, remember how we showed you to look for the size of the grains.

--Then, move the rock very close to the standard (point to the standard). Take some time to look back and forth between the rock and the standard several times.

--After you have checked carefully, tell me about the size of the rock's grains. Next, look at the labels on the board (point to labels) to find the correct square.

--Then place the rock where it belongs.

DEMONSTRATION DIALOGUE (Use Examples A and C)

--Watch while I demonstrate this for you.

Example A:

--First, remember how to look for the size of the grains.

--Move the rock very close to the standard. (move rock)

--Take some time to look back and forth between the rock and the standard several times. (point back and forth)

--Then, tell me whether the rock has larger grains, the same size grains, or smaller grains than the standard. This rock has larger grains than the standard.

--Then look at the labels on the board to find the correct square. This rock has larger grains than the standard (point to "larger") so it goes in this square (place in square 1). If a rock has the same size grains as the standard, I would also place it here.

COMPARISON TO STANDARD

Strategy Instructions (Continued) Grain Size

Example C:

--Here is another example.

--First, remember how to look for the size of the grains.

--Move the rock very close to the standard. (move rock)
Take some time to look back and forth between the rock and the standard (point back and forth)

--Then, tell me about the size of the grains. This rock has smaller grains than the standard.

--Then look at the labels on the board. This rock has smaller grains than the standard (point to "smaller") so it goes in this square (place in square 2).

--Do you have any questions about what I want you to do?

COMPARISON TO STANDARD

Strategy Instructions (Continued) Grain Size

Strategy Error Responses

V. (If proximate, correct verbal response, incorrect placement)

You told me about the size of the grains correctly but you put it in the wrong square. It should have been placed here (point). Be sure you look at the labels (point) before you put the rock in a square.

Note: After 4 incorrect trials in a row repeat demonstration with Example A.

COMPARISON TO STANDARD

Strategy Instructions (Continued) Grain Size

Strategy Error Responses

A correct trial must include all of the following:

(1) The rock is proximate to the standard.
(2) The verbal response is correct.
(3) The placement is correct.

FOR CORRECT TRIAL:

I. (If proximate, correct verbal response and placement)

Good! This rock has larger/the same size/smaller grains than the standard and was put here (point).

FOR ERRORS:

II. (If not proximate, correct verbal response)

Good! This rock has larger/the same size/smaller grains than the standard and was placed here (point). But you forgot to put the rock next to the standard. Be sure you do this (move rock to the standard). Take time to look back and forth carefully several times (point back and forth) before you tell me about the rock, and put it in a square.

III. (If not proximate, incorrect verbal response)

No! This rock has larger/the same size/smaller grains than the standard. You forgot to put the rock next to standard. Be sure you do this. (move rock to standard). Take time to look back and forth carefully several times (point back and forth) before you tell me about the rock, and put it in a square.

IV. (If proximate and incorrect verbal response)

No! This rock has larger/the same size/smaller grains than the standard and should be put here (point). Be sure you take time to look back and forth carefully several times (point back and forth) before you tell me about the rock, and put it in a square.

COMPARISON TO STANDARD

Feedback Instruction — Grain Size

--I want you to do this again. Be sure you look at the size of the grains again. Tell me if the rock I hand you has larger, the same size or smaller grains than the standard. Then place the rock where it belongs.

--This time I will tell you if you are right or wrong for each rock I hand you.

Example A:

--Here is an example (Place Example A in Square 1)

--This rock has <u>larger</u> grains than the standard. It goes in this square (point). If a rock has the same size grains as the standard, it would also go in this square.

Example C:

--Here is another example (Place Example C in Square 2)

--This rock has <u>smaller</u> grains than the standard. It goes in this square (point).

--Do you have any questions about what I want you to do?

COMPARISON TO STANDARD

Feedback Error Responses: Grain Size

A correct trial must include both of the following:

(1) correct verbal response.
(2) correct placement.

FOR CORRECT TRIAL:

I. (If correct verbal response and placement)

Good! This rock has larger/the same size/smaller grains than the standard and was put here (point).

FOR ERRORS:

II. (If correct verbal response and incorrect placement)

You told me about the size of the grains correctly but you put it in the wrong square. It should have been placed here (point).

III. If incorrect verbal response

No! This rock has larger/the same size/smaller grains than the standard and should be put here (point).

Note: After 4 incorrect trials in a row repeat demonstration with Example A and C.

SINGLE VARIABLE CLASSIFICATION

Pretest and General Task Instruction   Grain Size

--I want you to use this chart (point) to put each rock I hand you into the square where it belongs. Use the size of the grains to decide which square each rock should go in.

--The rocks with large grains go in this square (point), the rocks with small grains go in this square (point) and the rocks that are glassy go in this square (point).

--These rocks are standards (point). Rocks that have larger grains or the same size grains as this standard go here (point). They have large grains (point to label).

--Rocks that have smaller grains than this standard (point), but have larger grains or the same size grains as this standard (point) go here (point). They have small grains (point to label).

--Rocks that have smaller grains than this standard (point) go here (point). They are glassy (point to label).

--Remember, I want you to use the size of the grains to place each rock in the square where it belongs.

--Remember what you learned in your other lessons (pause). I want you to use what you have learned before to do this task.

--Do you have any questions about what I want you to do?

SINGLE VARIABLE CLASSIFICATION

Strategy Instructions Grain Size

--I want you to do this again with some new rocks. Remember I want you to place use the size of the grains to place each rock in the square where it belongs.

--Before you start I want to show you a way to do this.

--First, remember to look at the size of the grains.

--Check <u>this</u> standard first (point).

--If the rock does not go in the first square (point) then check the second standard (point).

--When you find the square the rock goes in, read the label for that square out loud.

--Then, place the rock in that square.

<u>DEMONSTRATION DIALOGUE</u> (Use Examples A, B, and D)

--Watch while I demonstrate this for you.

Example A:

--Move the rock close to the first standard (move rock). Take some time to look back and forth between the rock and the standard (point back and forth).

--This rock has larger grains than the first standard so read out loud "<u>large grains</u>" (point). Then place the rock in this square (place sample in cell).

--If a rock had the <u>same</u> size grains as this standard I would do the same thing.

Example B:

--Again, move the rock close to the first standard. Take some time to look back and forth between the rock and the standard.

--This rock has smaller grains then the first standard so you must use the next standard. (Move sample to next standard).

SINGLE VARIABLE CLASSIFICATION

Strategy Instructions (Continued) Grain Size

--Again, take time to look back and forth. This rock has larger grains than this standard so read "small grains", out loud and place the rock in this cell (place sample in cell).

--If a rock had the same size grains as this standard I would do the same thing.

Example D:

--Again move the rock close to the standard (move rock).

--This rock has smaller grains than the first standard, so you must use the next standard. (Move the sample to next standard)

--This rock has smaller grains than the standard. So read "glassy" out loud and place the rock in this cell. (Place sample in cells)

--Do you have any questions about what I want you to do?

SINGLE VARIABLE CLASSIFICATION

Strategy Instructions (Continued) Grain Size

Strategy Error Responses

A correct trial must include all of the following in order:

Cell 1 Sample	Cell 2 Sample	Cell 3 Sample
S proximate to A	S proximate to A	S proximate to A
V1	S proximate to B	S proximate to B
P1	V2	V3
	P2	P3

FOR CORRECT TRIAL:

I. Good! This rock has large grains/has small grains/is glassy and was put here (point).

FOR ERRORS:

II. (If incorrect placement but student's strategy is consistent with response.)

No! This rock has large grains/has small grains/is glassy.

(Move rock to standard where initial error was made.)

Be sure to take time to carefully look back and forth between the rock and the standard (point back and forth).

You ..'d have. . .

--placed the rock here (place).

or

--checked this standard too (point) and placed the rock here (place).

SINGLE VARIABLE CLASSIFICATION

Strategy Instructions (Continued) Grain Size

III. (If correct placement and incorrect strategy)

"The rock was placed correctly but you forgot to. . ." (use one of the following for first of strategy errors.)

or

IV. (If incorrect placement and incorrect strategy)

"No, this rock has large grains/has small grains/is glassy and should have been placed here (place sample in correct cell).

You forgot to. . . (use one of the following for first of strategy errors.)

ERROR:	RESPONSE:
not proximate to first or both standards	"begin with the rock close to the first standard" (move rock to first standard)
not proximate to second standard when required, i.e., P2, P3, samples.	"move the rock close to the second standard." (move rock to second standard)
--no verbal output	"read large grains/small grains/glassy - out loud before you placed the rock in this square (move rock to correct square).
* --uses second standard when sample is correct in cell 1	"to stop after you checked the first standard. If the rock has larger or the same size grains as this standard (point) you do not have to use the next standard (point).

SINGLE VARIABLE CLASSIFICATION

Strategy Instructions (Continued) Grain Size

* This response is used only when cell 1 placement was correct. This is <u>not</u> counted as an incorrect trial.

Note: After 4 errors in a row, repeat demonstration with Examples A, B, and D.

SINGLE VARIABLE CLASSIFICATION

Feedback Instructions　　　　　　　　　　　　　　　　Grain Size

--I want you to do this again with some new rocks. Remember I want you to place each rock in the square where it belongs. Be sure to use the size of the grains to decide where to place each rock.

--This time I will tell you if you are right or wrong for each rock I hand you.

--Here are some examples:

Example A --(Place rock) This rock has larger grains than this standard (point) so it goes in this square (point). It has large grains (point to label).

Example B--(Place rock) This rock has smaller grains than this standard. It has larger grains than this standard (point), so it goes in this square (point). It has small grains (point to label).

Example D--(Place rock) This rock has smaller grains than this standard (point), so it goes in this square (point). It is glassy (point to label).

--Do you have any questions about what I want you to do?

SINGLE VARIABLE CLASSIFICATION

Feedback Error Responses Grain Size

A correct trial requires:

(1) correct placement

FOR CORRECT TRIAL:

1. Good! This rock has large grains/has small grains/ is glassy and was put here (point).

FOR ERROR:

II. No! This rock has large grains/has small grains/is glassy and should be put here (point).

Note: After 4 incorrect trials in a row, repeat demonstration with Examples A, B, and D.

SINGLE VARIABLE CLASSIFICATION

Pretest and General Task Instruction

Amount of Light Colored Grains

--I want you to use this chart (point) to put each rock I hand you into the square where it belongs. Use the amount of light colored grains to decide which square each rock should go in.

--The rocks with mostly light grains go in this square (point), the rocks with about half light grains go in this square (point), and the rocks with mostly dark grains go in this square (point).

--These rocks are standards (point). Rocks with more light grains than this standard (point) go in this square (point). They have mostly light grains (point to label).

--Rocks with more dark grains than this standard (point), but more light grains or the same amount of light grains as this standard go in this square (point). They have about half light grains.

--Rocks with more dark grains than this standard go here (point). They have mostly dark grains.

--Remember what you learned in your other lessons. (Pause). I want you to use what you have learned before to do this.

--Do you have any questions about what I want you to do?

SINGLE VARIABLE CLASSIFICATION

Strategy Instructions

Amount of Light Colored Grains

--I want you to do this again with some new rocks. Remember I want you to use the amount of light colored grains to place each rock in the square where it belongs.

--First, remember to look for the amount of light colored grains.

--Check this standard first (point).

--If the rock does not go in the first square, then check the second standard (point).

--When you find the square the rock goes in, read the label for that square out loud.

--Then, place the rock in that square.

<u>DEMONSTRATION DIALOGUE</u> (Use Examples A, B, and C)

--Watch while I demonstrate for you.

Example A:

--Move the rock close to the first standard. (Move rock). Take some time to look back and forth between the rock and the standard. (Point back and forth).

--This rock has more light grains than this standard (point) so read "<u>mostly light grains</u>" out loud. Then place the rock in this square (place sample in cell 1).

--If a rock had the same amount of light grains as this standard I would do the same thing.

Example B:

--Again, move the rock close to the first standard. (Move rock). Take some time to look back and forth between the rock and the standard.

--This rock has more dark grains than this standard (point) so you must use the next standard (move sample to the next standard).

SINGLE VARIABLE CLASSIFICATION

Strategy Instructions (Continued) | Amount of Light Colored Grains

--Again take time to look back and forth. This rock has more light grains than this standard, so read "about half light grains" out loud and place the rock in this square (place rock in cell 2).

--If a rock nad the same amount of light grains as this standard I would do the same thing.

Example C:

--Again move the rock close to the standard. (Move rock)

--This rock has more dark grains than this standard (point) so you must use the next standard (move sample to next standard).

--This rock has more dark grains than this standard too so read "mostly dark grains" out loud and place the rock in this square (place sample in cell 3).

SINGLE VARIABLE CLASSIFICATION

Strategy Instruction (Continued) — Amount of Light Colored Grains

Strategy Error Responses

A correct trial must include all of the following in order.

Cell 1 Sample	Cell 2 Sample	Cell 3 Sample
S proximate to C	S proximate to C	S proximate to C
V1	S proximate to D	S proximate to D
P1	V2	V3
	P2	P3

FOR CORRECT TRIAL:

I. Good! This rock has mostly light grains/about half light grains/ mostly dark grains and was put here (point).

FOR ERRORS:

II. (If incorrect placement but child's strategy is consistent with response)

No! This rock has mostly light/about half light/mostly dark grains.

(Move rock to standard where initial error was made)

Be sure to take time to carefully look back and forth between the rock and the standard (point back and forth).

You should have. . .

--placed the rock here (place).

or

--checked this standard (point) too and placed the rock here (place).

SINGLE VARIABLE CLASSIFICATION

Strategy Instruction (Continued)

Amount of Light Colored Grains

III. (If correct placement and incorrect strategy.)

"The rock was placed correctly but you forgot to. . ." (use one of following for first of strategy errors.)

IV. (If incorrect placement and incorrect strategy)

No, this rock has mostly light grains/about half light grains/mostly dark grains and should have been placed here (place sample in correct cell). You forgot to. . . (use one of following for first of strategy errors.)

Error:	Response:
Not proximate to first or both standards.	"begin by putting the rock close to the first standard" (Move rock to first standard)
Not proximate to second standard when required, i.e., P2, P3 samples.	"move the rock to the second standard." (Move rock to second standard)
--no verbal out put	"read mostly light grains/about half light grains/mostly dark grains out loud before you placed the rock in this square (Move rock to correct square)
* --uses second standard when sample is correct in cell 1.	"to stop after you checked the first standard. If the rock has more or the same amount of light grains as this standard (point) you do not have to use the next standard (point).

*This response is used only when cell 1 placement was correct. This does not count as an incorrect trial.

Note: After 4 incorrect trials in a row, repeat demonstration with Examples A, B, and C.

SINGLE VARIABLE CLASSIFICATION

Feedback Instructions

Amount of Light Colored Grains

--I want you to do this again with some new rocks. Remember I want you to place each rock in the square where it belongs. Be sure to use the amount of light colored grains to decide where to place each rock.

--This time I will tell you if you are right or wrong for each rock I hand you.

--Here are some examples:

Example A--(Place rock) This rock has more light grains than this standard (point) so it goes in this square (point). It has mostly light grains (point to label).

Example B--(Place rock) This rock has more dark grains than this standard (point). It has more light grains than this standard (point) so it goes in this square (point). It has about half light grains (point to label).

Example C--(Place rock) This rock has more dark grains than this standard (point) so it goes in this square. It has mostly dark grains (point to label).

--Do you have any questions about what I want you to do?

SINGLE VARIABLE CLASSIFICATION

Feedback Error Responses

Amount of Light
Colored Grains

A correct trial requires:

(1) correct placement

FOR CORRECT TRIAL:

I. Good! This rock has mostly light grains/about half light grains/mostly dark grains and was put here (point).

FOR ERROR:

II. No! This rock has mostly light grains/about half light grains/mostly dark grains and should be put here (point).

Note: After 4 incorrect trials in a row, repeat demonstration with Examples A, B, and C.

DOUBLE VARIABLE CLASSIFICATION

General Task Instructions and Pretest

--I want you to use this chart (point) to put each rock I hand you into the square where it belongs. Use both the size of the grains (point) and the amount of light colored grains in the rock (point) to decide which square each rock should go in.

--For grain size, rocks with large grains go in this row (point), rocks with small grains go in this row (point) and glassy rocks go in this row. See how each row (point) goes all the way across.

--These rocks are standards (point). Rocks that have larger grains or the same size grains as this standard go in this row (point). They have large grains (point to label).

--Rocks that have smaller grains than this standard (point), but have larger grains or the same size grains as this standard (point) go in this row (point). They have small grains (point to label).

--Rocks that have smaller grains than this standard (point) go in this row (point). They are glassy (point to label).

--For the amount of light colored grains, rocks with mostly light grains go in this column (point), rocks with about half light grains go in this column (point), and rocks with mostly dark grains go in this column (point). See how each column goes all the way up.

--These rocks are standards (point). Rocks with more light grains or the same amount of light grains as this standard (point) go in this column (point). They have mostly light grains (point to label).

--Rocks with more dark grains than this standard (point), but more light grains or the same amount of light grains as this standard go in this column (point). They have about half light grains.

--Rocks with more dark grains than this standard go in this column (point). They have mostly dark grains (point to label).

--Remember what I want you to do is place rock in the square where it belongs. For example, a rock with large grains (point to label) and mostly light grains (point to label) would go here (point). A rock with small grains (point) and about half light grains (point to label) would go here (point).

--Do you have any questions about what I want you to do?

DOUBLE VARIABLE CLASSIFICATION

Strategy Instructions

--I want you to do this again with some new rocks. Before you start I want to show you a way to do this. Be sure you use <u>both</u> the size of the grains and the amount of light colored grains to decide where to place each rock.

--First, use grain size (point to label) to decide which <u>row</u> the rock should go in (point to rows).

--Check this standard (point) first. If the rock does not go in the first row, then check the second standard (point).

--After you find the row the rock goes in, read the label for that row out loud.

--Next, use the amount of light colored grains (point to label) to decide which <u>column</u> the rock should go in (point to columns).

--Check this standard (point) first. If the rock does not go in the first column, then check the last standard (point).

--After you find the column the rock goes in, read the label for that column out loud. Then remember the correct row and place the rock in the square where it belongs.

DOUBLE VARIABLE CLASSIFICATION

DEMONSTRATION DIALOGUE (Use Examples A, B, and C)

--Watch while I demonstrate this.

Example A:

--First use the size of the grains to decide which row the rock goes in (point to label and rows).

--Move the rock close to the first standard. (Move sample proximate to Standard A). Take some time to look back and forth between the rock and the standard.

--This rock has larger grains than the first standard so I know that it goes in this row (point).

--Now read the label "large grains" out loud.

--Next, use the amount of light colored grains to decide which column the rock goes in (point to label and column).

--(Hold rock proximate to Stanard C). The rock has more light grains than this standard so I know that it goes in this column (point).

--Then read the label "mostly light grains" out loud.

--The correct row was "large grains" so I place the rock in this square (place rock).

Example B:

--Here is another example.

--First, use the size of the grains to decide which row the rock goes in.

--(Hold sample proximate to Standard A) This rock has smaller grains than the first standard, so I have to check the next standard.

--(Hold sample proximate to Standard B) The rock has larger grains than this standard, so it goes in this row (point to row).

--Read "small grains" out loud.

--Next, use the amount of light colored grains to decide which column the rock goes in.

DOUBLE VARIABLE CLASSIFICATION

DEMONSTRATION DIALOGUE (Continued)

--(Hold sample proximate to Standard C) The rock has more dark grains than this standard, so I have to check the next one.

--(Hold sample proximate to Standard D) It has more light grains than this standard, so it goes in this column (point to column), and I read "about half light grains" out loud.

--The correct row was "small grains" so I place the rock in this square (place rock).

Example C:

--Here is one more example.

--(Hold sample proximate to Standard A, then to Standard B) It has the same size grains as this standard, so it goes in this row (point to row).

--Read "small grains" out loud. (Hold sample proximate to Standard C).

--The rock has more dark grains than this standard. (Hold sample proximate to Standard D).

--It has more dark grains than this standard, too. It goes in this column (point to column).

--Read the label "mostly dark grains."

--The correct row was "small grains" so I place the rock in this square (place rock).

Now I want you to try some rocks doing it the way I showed you.

--Do you have any questions about how I want you to do this?

DOUBLE VARIABLE CLASSIFICATION

Strategy Instructions (Continued)

Strategy Error Responses

A correct trial must include all of the following:

1. Proximity of sample to standard in correct sequence.

2. Correct verbal output for each variable.

3. Correct placement.

Except: If a student checks standard B after standard A or D after C when it is not necessary, the trial is still correct if the corresponding verbal response "large grains" or "mostly light grains" is correctly stated.

FOR CORRECT TRIAL:

1. Good! This rock has large grains/has small grains/is glassy and has mostly light grains/about half light grains/ mostly dark grains and was put here (point).

FOR ERRORS:

II. (If incorrect placement but student's strategy is consistent with response)

NO! This rock has large grains/has small grains/is glassy and has mostly light/about half light/mostly dark grains.

(Move rock to standard where initial error was made)

Be sure to take time to carefully look back and forth between the rock and the standards you use (point back and forth).

You should have. . .

--placed the rock here (place)

or

--checked this/these standards (point) and placed the rock here (place).

DOUBLE VARIABLE CLASSIFICATION

Strategy Instructions (Continued)

Strategy Error Responses (Continued)

III. If correct placement and incorrect strategy)

"The rock was placed correctly but you forgot to. . ."
(use one of the following for first of strategy errors.)

or

IV. (If incorrect placement and incorrect strategy)

"No, this rock had large grains/has small grains/is glassy and has mostly light grains/about half light grains/mostly dark grains. It should have been placed here (place sample in correct cell).

You forgot to. . . (use one of the following for first of strategy errors.)

	ERROR:	RESPONSE:
GRAIN SIZE	not proximate to first or both grain size standards	"begin with the rock close to the first standard" (move rock to first standard)
	not proximate to second grain size standard when required, i.e., row 2, row 3 samples.	"move rock close to the second standard." (Move rock to second standard)
	no verbal output for grain size	"read large grains/small grains/glassy-out load before you placed the rock in this square (move rock to this square).

DOUBLE VARIABLE CLASSIFICATION

Strategy Instructions (Continued)

AMOUNT OF LIGHT GRAINS

not proximate to first or both amount light grain standards	"put the rock close to the first standard down here." (Move rock to first standard.)
not proximate to second amount light grain standard when required, i.e., column 2 or column 3 samples	"move rock close to the second standard." (Move rock to second standard.)
no verbal output for amount light grain.	"read large grains/small grains/glassy-out loud before you placed the rock in this square." (Move rock to correct square.)

AMOUNT OF LIGHT GRAINS OR GRAIN SIZE

* --uses second standard when sample is correctly placed.	"to stop after you checked the first standard. If the rock has larger or the same size grains as this standard (point) you do not have to use the next standard (point)."

*This response is used only when row 1 and/or column 1 placement was correct. This does not count as a correct trial.

Note: After each set of 4 consecutive errors repeat demonstration with <u>one</u> sample. Begin with sample B. After the next set of 4 consecutive errors use C, then A. Repeat sequence if necessary.

DOUBLE VARIABLE CLASSIFICATION

Feedback Instructions

--I want you to do this again with some new rocks. Remember I want you to place each rock in the square where it belongs. Be sure you use both the size of the grains and the amount of light colored grains to decide where to place each rock.

--This time I will tell you if you are right or wrong for each rock I hand you.

Example A--(Place rock in Cell 1) This rock has larger grains than this standard (point to Standard A) so it goes in this row (point to row).

--It has more light grains than this standard (point to Standard C) so it goes in this column (point to column). It has mostly light grains (point to label). It belongs in this square (point).

Example B--(Place the rock in Cell 5) This rock has smaller grains than this standard (point to standard A). It has larger grains than this standard (point to Standard B), so it goes in this row (point to row). It has small grains (point to label).

--It has more dark grains than this standard (point to Standard C). It has more light grains than this standard (point to Standard D). So it goes in this column (point to column). It has about half light grains (point to label). It belongs in this square (point).

Example C--(Place rock in Cell 6) This rock has the same size grains as this standard (point to Standard B) so it goes in this row (point to row). It has small grains (point to label).

--It has more dark grains than this standard (point to Standard D) so it goes in this column (point to column). It has mostly dark grains (point to label). It belongs in this square (point).

SINGLE VARIABLE CLASSIFICATION

Feedback Error Responses

Amount of Light
Colored Grains

A correct trial requires:

(1) correct placement

FOR CORRECT TRIAL

I. Good! This rock has large grains/has small grains/is glassy and mostly light grains/about half light grains/mostly dark grains and was put here (point).

FOR ERROR:

II. No, this rock has large grains/has small grains/is glassy and has mostly light grains/about half light grains/mostly dark grains. It should have been placed here (place sample in correct cell).

Note: After each set of 4 consecutive errors repeat demonstration with one sample. Begin with sample B. After the next 4 consecutive errors use C, then A. Repeat sequence if necessary.

APPENDIX D

SCORE SHEETS

APPENDIX D

SCORE SHEETS

The following data sheets were used during pretests, instruction, and posttests for all students. Each instructor reported the observable student actions by using a series of the symbols shown at the bottom of each page. The typed series of symbols shown under the heading Sequence of Actions indicated actions which were observed if the students placed the sample exactly as taught during strategy instruction. The recording of additional symbols was not necessary if the sample was placed in this way. In addition to the symbols shown, the number of second-counts the student compared the sample to a standard was recorded for the Comparison to Standard Task and the pretests for the Single Variable Classification Task. The time was recorded as a subscript with the symbol for the appropriate standard(s).

The Passed-Trial column was used during instruction. If a student correctly placed the sample following the instructions, the column was checked. Additional comments included recording instructor errors and questions as well as additional description of student behaviors.

COMPARISON TO STANDARD
Grain Size-Set A

Order No.	Rock No.					Sequence of Actions						Passed Trial?	Comments
1	10		A	V3	b	P2							
2	8		A	V3	b	P2							
3	16		A	V3	b	P2							
4	18		A	V1	b	P1							
5	21		A	V3	b	P2							
6	6		A	V3	b	P2							
7	13		A	V1	b	P1							
8	2		A	V1	b	P1							
9	23		A	V3	b	P2							
10	7		A	V1	b	P1							
11	19		A	V1	b	P1							
12	15		A	V1	b	P1							
13	14		A	V1	b	P1							
14	24		A	V3	b	P2							
15	3		A	V3	b	P2							
16	17		A	V3	b	P2							
17	20		A	V1	b	P1							
18	30		A	V1	b	P1							
19	9		A	V1	b	P1							
20	12		A	V3	b	P2							
21	25		A	V1	b	P1							
22	11		A	V1	b	P1							
23	5		A	V1	b	P1							
24	1		A	V3	b	P2							

KEY: S - Looks at sample
V - Verbal response (response #)
b - Looks at board
P - Places rock (square #)
A - Looks at sample proximate to standard A

Student ____________________

Tester ______________ Date __________

Pretest Strategy   Instruction Feedback   Post test

COMPARISON TO STANDARD
Grain Size-Set B

Order No.	Rock No.	Sequence of Actions									Passed Trial?	Comments
1	28	A	V1	b	P1							
2	31	A	V3	b	P2							
3	35	A	V2	b	P1							
4	42	A	V1	b	P1							
5	49	A	V3	b	P2							
6	50	A	V3	b	P2							
7	39	A	V3	b	P2							
8	44	A	V1	b	P1							
9	29	A	V1	b	P1							
10	38	A	V3	b	P2							
11	43	A	V1	b	P1							
12	40	A	V3	b	P2							
13	36	A	V3	b	P2							
14	33	A	V1	b	P1							
15	45	A	V3	b	P2							
16	46	A	V1	b	P1							
17	47	A	V1	b	P1							
18	37	A	V2	b	P1							
19	48	A	V3	b	P2							
20	34	A	V1	b	P1							
21	27	A	V3	b	P2							
22	22	A	V3	b	P2							
23	32	A	V1	b	P1							
24	26	A	V3	b	P2							

KEY: S - Looks at sample
V - Verbal response (response #)
b - Looks at board
P - Places rock (square #)
- Looks at sample proximate to standard

Student ____________________

Tester ______________ Date __________

Pretest Strategy   Instruction Feedback   Post test

COMPARISON TO STANDARD
Amount of Light Colored Grains-Set A

Order No.	Rock No.	Sequence of Actions										Passed Trial?	Comments
1	10	C	V3	b	P2								
2	8	C	V1	b	P1								
3	16	C	V1	b	P1								
4	18	C	V3	b	P2								
5	21	C	V1	b	P1								
6	6	C	V3	b	P2								
7	13	C	V3	b	P2								
8	2	C	V1	b	P1								
9	23	C	V3	b	P2								
10	7	C	V1	b	P1								
11	19	C	V3	b	P2								
12	15	C	V3	b	P2								
13	14	C	V1	b	P1								
14	24	C	V3	b	P2								
15	3	C	V3	b	P2								
16	17	C	V1	b	P1								
17	20	C	V1	b	P1								
18	30	C	V3	b	P2								
19	9	C	V3	b	P2								
20	12	C	V3	b	P2								
21	25	C	V1	b	P1								
22	11	C	V3	b	P2								
23	5	C	V3	b	P2								
24	1	C	V3	b	P2								

KEY: S - Looks at sample
V - Verbal response (response #)
b - Looks at board
P - Places rock (square #)
C - Looks at sampe proximate to standard C

Student ______________________

Tester ______________ Date __________

Pretest Strategy Instruction Feedback Post test

COMPARISON TO STANDARD
Amount of Light Colored Grains-Set B

Order No.	Rock No.	Sequence of Actions									Passed Trial?	Comments
1	28	C	V3	b	P2							
2	31	C	V3	b	P2							
3	35	C	V1	b	P1							
4	42	C	V3	b	P2							
5	49	C	V3	b	P2							
6	50	C	V1	b	P1							
7	39	C	V1	b	P1							
8	44	C	V1	b	P1							
9	29	C	V1	b	P1							
10	38	C	V3	b	P2							
11	43	C	V3	b	P2							
12	40	C	V1	b	P1							
13	36	C	V1	b	P1							
14	33	C	V3	b	P2							
15	45	C	V1	b	P1							
16	46	C	V3	b	P2							
17	47	C	V3	b	P2							
18	37	C	V3	b	P2							
19	48	C	V1	b	P1							
20	34	C	V1	b	P1							
21	27	C	V3	b	P2							
22	22	C	V3	b	P2							
23	32	C	V1	b	P1							
24	26	C	V3	b	P2							

KEY: S - Looks at sample
V - Verbal response (response #)
b - Looks at board
P - Places rock (square #)
C - Looks at sample proximate to standard C

Student ____________________

Tester ______________ Date __________

Pretest Strategy   Instruction Feedback   Post test

SINGLE VARIABLE CLASSIFICATION TASK
Grain Size-Set A

Order No.	Rock No.		Sequence of Actions									Passed Trial?	Comments
1	10		A	B	M	V2	P2						
2	8		A	B	M	V2	P2						
3	16		B	B	M	V2	P2						
4	18		A	L	V1	P1							
5	21		A	B	M	V2	P2						
6	50		A	B	M	V2	P2						
7	13		A	L	V1	P1							
8	2		A	L	V1	P1							
9	23		A	B	M	V2	P2						
10	7		A	L	V1	P1							
11	19		A	L	V1	P1							
12	15		A	L	V1	P1							
13	14		A	L	V1	P1							
14	24		A	B	M	V2	P2						
15	3		A	B	M	V2	P2						
16	17		A	B	M	V2	P2						
17	20		A	L	V1	P1							
18	30		A	L	V1	P1							
19	9		A	L	V1	P1							
20	12		A	B	R	V3	P3						
21	25		A	L	V1	P1							
22	11		A	L	V1	P1							
23	5		A	L	V1	P1							
24	1		A	B	M	V2	P2						

KEY: S - Looks at sample
V - Verbal response (response #)
P - Places rock (square #)
A, B - Looks at sample proximate to standard A, B
L, M, R - Looks at left, middle, right of board

Student ______________________

Tester ______________ Date __________

Pretest Strategy   Instruction Feedback   Post test Iso-feedback

SINGLE VARIABLE CLASSIFICATION TASK
Grain Size-Set B

Order No.	Rock No.	Sequence of Actions										Passed Trial?	Comments
1	28		A	L	V1	P1							
2	31		A	B	M	V2	P2						
3	35		A	L	V1	P1							
4	42		A	L	V1	P1							
5	49		A	B	M	V2	P2						
6	6		A	B	M	V2	P2						
7	39		A	B	M	V2	P2						
8	44		A	L	V1	P1							
9	29		A	L	V1	P1							
10	38		A	B	M	V2	P2						
11	43		A	L	V1	P1							
12	40		A	B	M	V2	P2						
13	36		A	B	R	V3	P3						
14	33		A	L	V1	P1							
15	45		A	B	M	V2	P2						
16	46		A	L	V1	P1							
17	47		A	L	V1	P1							
18	37		A	L	V1	P1							
19	48		A	B	M	V2	P2						
20	34		A	L	V1	P1							
21	27		A	B	M	V2	P2						
22	22		A	B	M	V2	P2						
23	32		A	L	V1	P1							
24	26		A	B	M	V2	P2						

KEY: S - Looks at sample
V - Verbal response (response #)
P - Places rock (square #)
A, B - Looks at sample proximate to standard A, B
L, M, R - Looks at left, middle, right of board

Student ______________________

Tester ______________ Date __________

Pretest Strategy   Instruction Feedback   Post test Iso-feedback

SINGLE VARIABLE CLASSIFICATION TASK
Amount of Light Colored Grains-Set A

Order No.	Rock No.	Sequence of Actions										Passed Trial?	Comments
1	10		C	D	R	V3	P3						
2	8		C	L	V1	P1							
3	16		C	L	V1	P1							
4	18		C	D	M	V2	P2						
5	21		C	L	V1	P1							
6	50		C	L	V1	P1							
7	13		C	D	M	V2	P2						
8	2		C	L	V1	P1							
9	23		C	D	R	V3	P3						
10	7		C	L	V1	P1							
11	19		C	D	M	V2	P2						
12	15		C	D	R	V3	P3						
13	14		C	L	V1	P1							
14	24		C	D	M	V2	P2						
15	3		C	D	R	V3	P3						
16	17		C	D	M	V2	P2						
17	20		C	L	V1	P1							
18	30		C	D	M	V2	P2						
19	9		C	D	R	V3	P3						
20	12		C	D	R	V3	P3						
21	25		C	L	V1	P1							
22	11		C	D	M	V2	P2						
23	5		C	D	M	V2	P2						
24	1		C	D	R	V3	P3						

KEY: S - Looks at sample
V - Verbal response (response #)
P - Places rock (square #)
C, D - Looks at sample proximate to standard C, D
L, M, R - Looks at left, middle, right of board

Student ______________________

Tester ______________ Date ____________

Pretest Strategy   Instruction Feedback   Post test Iso-feedback

SINGLE VARIABLE CLASSIFICATION TASK
Amount of Light Colored Grains-Set A

Order No.	Rock No.	Sequence of Actions										Passed Trial?	Comments
1	10		C	D	R	V3	P3						
2	8		C	L	V1	P1							
3	16		C	L	V1	P1							
4	18		C	D	M	V2	P2						
5	21		C	L	V1	P1							
6	50		C	L	V1	P1							
7	13		C	D	M	V2	P2						
8	2		C	L	V1	P1							
9	23		C	D	R	V3	P3						
10	7		C	L	V1	P1							
11	19		C	D	M	V2	P2						
12	15		C	D	R	V3	P3						
13	14		C	L	V1	P1							
14	24		C	D	M	V2	P2						
15	3		C	D	R	V3	P3						
16	17		C	D	M	V2	P2						
17	20		C	L	V1	P1							
18	30		C	D	M	V2	P2						
19	9		C	D	R	V3	P3						
20	12		C	D	R	V3	P3						
21	25		C	L	V1	P1							
22	11		C	D	M	V2	P2						
23	5		C	D	M	V2	P2						
24	1		C	D	R	V3	P3						

KEY: S - Looks at sample
V - Verbal response (response #)
P - Places rock (square #)
C, D - Looks at sample proximate to standard C, D
L, M, R - Looks at left, middle, right of board

Student ____________________

Tester ______________ Date __________

Pretest Strategy　　Instruction Feedback　　Post test Iso-feedback

SINGLE VARIABLE CLASSIFICATION TASK
Amount of Light Colored Grains-Set B

Order No.	Rock No.	Sequence of Actions										Passed Trial?	Comments
1	28		C	D	M	V2	P2						
2	31		C	D	R	V3	P3						
3	35		C	L	V1	P1							
4	42		C	D	M	V2	P2						
5	49		C	D	R	V3	P3						
6	6		C	D	M	V2	P2						
7	39		C	L	V1	P1							
8	44		C	L	V1	P1							
9	29		C	L	V1	P1							
10	38		C	D	M	V2	P2						
11	43		C	D	R	V3	P3						
12	40		C	L	V1	P1							
13	36		C	L	V1	P1							
14	33		C	D	M	V2	P2						
15	45		C	L	V1	P1							
16	46		C	D	R	V3	P3						
17	47		C	D	M	V2	P2						
18	37		C	D	M	V2	P2						
19	48		C	L	V1	P1							
20	34		C	L	V1	P1							
21	27		C	D	R	V3	P3						
22	22		C	D	M	V2	P2						
23	32		C	L	V1	P1							
24	26		C	D	R	V3	P3						

Key: S - Looks at sample
V - Verbal response (response #)
P - Places rock (square #)
C, D - Looks at sample proximate to standard C, D
L, M, R - Looks at left, middle, right of board

Student ______________________

Tester ______________ Date ___________

Pretest Strategy   Instruction Feedback   Post test Iso-feedback

DOUBLE VARIABLE CLASSIFICATION TASK
SET A

Order No.	Rock No.	Sequence of Actions											Passed Trial?	Comments
1	10	A	B		V2	C	D		V6		P6			
2	8	A	B		V2	C		V4		P4				
3	16	A	B		V2	C		V4		P4				
4	18	A		V1	C	D		V5		P2				
5	21	A	B		V2	C		V4		P4				
6	50	A	B		V2	C		V4		P4				
7	13	A		V1	C	D		V5		P2				
8	2	A		V1	C		V4		P1					
9	23	A	B		V2	C	D		V6		P6			
10	7	A		V1	C		V4		P1					
11	19	A		V1	C	D		V5		P2				
12	15	A		V1	C	D		V6		P3				
13	14	A		V1	C		V4		P1					
14	24	A	B		V2	C	D		V5		P5			
15	3	A	B		V2	C	D		V6		P6			
16	17	A	B		V2	C	D		V5		P5			
17	20	A		V1	C		V4		P1					
18	30	A		V1	C	D		V5		P2				
19	9	A		V1	C	D		V6		P3				
20	12	A	B		V3	C	D		V6		P9			
21	25	A		V1	C		V4			P1				
22	11	A		V1	C	D		V5		P2				
23	5	A		V1	C	D		V5		P2				
24	1	A	B		V2	C	D		V6		P6			

KEY: S - Looks at sample
V x - Verbal response (response #)
P - Places rock (square #)
A, B, C, D - Looks at sample proximate to standard A, B, C, D
G, L - Looks at Gn Sz./Amt. Lt. Gns. part of board

Student ____________________

Tester ____________ Date ____________

Pretest Strategy   Instruction Feedback   Post test Iso-feedback

DOUBLE VARIABLE CLASSIFICATION TASK
SET B

Order No.	Rock No.						Sequence of Actions							Passed Trial?	Comments
1	28		A		V1	C	D		V5		P2				
2	31		A	B		V2	C	D		V6	P6				
3	35		A		V1	C		V4		P1					
4	42		A		V1	C	D		V5		P2				
5	49		A	B		V2	C	D		V6		P6			
6	6		A	B		V2	C	D		V5		P5			
7	39		A	B		V2	C		V4		P4				
8	44		A		V1	C		V4		P1					
9	29		A		V1	C		V4		P1					
10	38		A	B		V2	C	D		V5		P5			
11	43		A		V1	C	D		V6		P3				
12	40		A	B		V2	C		V4		P4				
13	36		A	B		V3	C		V4		P7				
14	33		A		V1	C	D		V5		P2				
15	45		A	B		V2	C		V4		P4				
16	46		A		V1	C	D		V6		P3				
17	47		A		V1	C	D		V5		P2				
18	37		A		V1	C	D		V5		P2				
19	48		A	B		V2	C		V4		P4				
20	34		A		V1	C		V4		P1					
21	27		A	B		V2	C	D		V6	P6				
22	22		A	B		V2	C	D		V5	P5				
23	32		A		V1	C		V4		P1					
24	26		A	B		V2	C	D		V6	P6				

KEY: S - Looks at sample
V x - Verbal response (response #)
P - Places rock (square #)
A, V, D, D - Looks at sample proximate to standard A, B, C, D
G, L - Looks at Gn. Sz./Amt. Lt. Gns. part of board

Student ____________________

Tester_______________Date__________

Pretest Strategy   Instruction Feedback   Post test Iso-feedback

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