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ON-LINE COMPUTER TERMINAL PERFORMANCE
ON SCIENCE RELATED TASKS
OF CONCEPT-ATTAINMENT

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

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CHAPTER I

INTRODUCTION

There has been a good deal of discussion among educators concerning the individualization of instruction. This individualization may be accomplished by a variety of methods. "Permitting students some choice in determining the skills they will learn, developing alternative instructional sequences for teaching skills and establishing organizational procedures that permit students to progress at different rates, are examples of how such programs yield truly individualized educational environments" (Ferguson, 1971, p.1). Suppes (1964, p.82) expressed firm support for such moves when he stated that "the greatest improvement in subject-matter learning will result from an almost single minded concentration on individual differences." The different methods of individualization could be based on various individual differences such as subject's interest, rate of progress, abilities, or content background. Glaser (1970, p.17) summarizes a discussion of individual differences in the following manner:

> Individual differences are a basic element in any theory of instruction that underlies educational practice. Deep understanding is required of the manner in which the existing performance capabilities of our students, whatever the origin of these capabilities, interact with the conditions provided for learning. ...so that the optimal educational conditions can be provided to learners.

Gallagher (1970, p.47) expresses similar feelings in his statement that "if we are ever to completely individualize our educational system, there exists a strong need to devote more research activity in determining the interaction between conditions of instruction and the characteristics of the learner."

These characteristics or individual differences appear to manifest themselves in several different ways and in various forms of learning. Two of the major kinds of learning proposed by Gagne (1965) are "concept-formation" and "problem-solving". Voelker (1969, p.7) relates concept-formation to the learning of science in the following manner: "The processes of concept formation are analogous to the processes of scientific inquiry and discovery." These processes may be cognitive procedures which are related to those used in solving problems. Bloom and Broder (1950, p.3) stated that it might be possible to "infer the nature of the thought processes used by individuals in solving problems from the nature of the answers or selections made by the individual." Bloom and Broder (1950, p.303) also wrote:

> We are convinced, however, that a study of problem-solving processes is basic to an understanding of individual differences--their measurement and control. The development of more refined techniques of getting evidence on the processes of thinking, the creation of a symbolic system for representing the processes, and the discovery of a set of criteria to insure adequacy of sampling of problems are necessary tools which must be perfected before research in this field can be greatly improved or stabilized.

Within a few years of this report, Bruner, Goodnow, and Austin (1956) wrote about the development of some techniques and symbolic systems for representing the thought processes of individuals. These thought processes were inferred from a study of the response patterns used by subjects in solving problems involving concept-attainment. Bourne (1965, p.46) considers "the subject's individual overt responses to be related systematically to and indicative of his strategy or plan of attack on the problem". Bruner, Goodnow, and Austin (1956) also define strategy in terms of conscious decisions on the part of the individual expressed as a "pattern of decisions." Restle (1962) defines strategy as the pattern of responses by an individual. Since the responses of the individual rather than the rationale for the decision were the only basis for observations in this study, the sequence and type of selections were identified as the pattern for the individual. There seem to be distinct patterns in evidence in several studies (Bruner, Goodnow, and Austin, 1956) and these seem to be consistent from task to task for individuals. Bourne (1965, p.46) suggested that "the use of detailed analyses of responses sequences in an effort to get at the more precise characteristics of performance" is an experimental technique worth investigating further.

The sequences used by individuals in selecting information during the solving of a problem and patterns in these selections were investigated.

Statement of the Problem

This study was designed to identify the relations of patterns for the selections made by individuals during the attainment of a concept to individual characteristics.

1) Are identifiable patterns present in selection sequences during the attaining of concepts?

2) Are patterns related to individual characteristics?

3) Are patterns related to other performance measures?

In addition this study was designed to determine the effects of changes in the tasks upon the patterns used.

4) Does the nature of the task change the patterns?

In order to determine if individual patterns exist for the situation under study, it is necessary to measure whether individuals use the same patterns from one task to the next and whether different patterns are evident for different individuals.

The Tasks

The tasks developed were similar to Experiment 33 in the Chemical Education Material Study Laboratory Manual (Malm, 1963, p.86). The task involved the simulation of an analysis problem in which the student was asked to identify the chemical tests which might be used to determine the presence of a substance. The student requested the results of one of three tests(attributes) on one of four liquids (instances). Two of the four liquids were given as containing an unknown substance or contamination. The order and type of request made by the subject during the obtaining of information for the problem were considered as the pattern of selections.

Selection of Variables

In studying the strategies of individuals and their performance on tasks of concept-attainment , several variables have been reported. An extensive outline of these has been given by

Klausmeier et. al. (1965). Bourne (1965) identifies two categories of variables which were used in this study: differences in organismic characteristics and task characteristics. Organismic characteristics will be further subdivided into individual characteristics, those dealing with the background of the individual, and performance characteristics, those dealing with the performance of the individual on the task.

Task Characteristics

One aspect of studies on tasks of concept-learning which has produced ambiguous results is the effect of instructions. Several studies indicate that different instructions as to what is expected of the subject during the task do not produce significant differences in performance tasks of concept-learning (Archer, 1955, Denney, 1960, and Pyle, 1970). These studies, however, were made with concepts which normally would not be taught to the students in an instructional setting.

The effect of variations in the presentation of the stimuli during the task has been a major subject of study in concept-learning. A study of random versus ordered display of instances in a task in concept-attainment conducted by Laughlin (1964, 1965) showed no significant differences between those two methods. However, Bruner and others (1956) indicated a significant difference with individuals having less difficulty in attaining the concept from an ordered display than from a random display. Shephard and others (1961) found that subjects had less difficulty in attaining concepts if the attributes of the instances were displayed in a compact manner rather than distributed across the display.

The difficulty of a task of attribute-identification has been related to the amount of information given in a task in which the number of relevant attribute is given is easier than a task in which the number of relevant attributes is not given (Kendler, 1961, and Glazer, 1963).

Individual Characteristics

Several investigations have been conducted on the relationship of sex of subject to performance on tasks of concept-learning. The investigators indicated no differences between males and females in conceptual behavior (Klausmeier et. al., 1965, Fredrick, 1965, and Tagatz, 1967).

Klausmeier and others (1965) also investigated the relationship of major field of study of college students to the efficiency of learning concepts. Conflicting results were obtained in two experiments, one of which indicated no significant differences, while the other indicated that Home Economics, Speech and Foreign Language majors were most efficient with Agriculture, English and Physical Education (men) the least efficient.

In a series of studies, Osler with others have explored the relationship of intelligence to the learning of concepts (Osler and Fivel, 1961, Osler and Trautman, 1961, and Osler and Weiss, 1962). A higher intelligence appeared to produce more rapid learning of concepts with general instructions but no significant differences with specific instructions. Rooze (1969) found a significantly greater efficiency in tasks of concept-attainment in subjects with higher intelligence than those with lower intelligence as measured by IQ tests.

Performance Characteristics

The sequences used by subjects in tasks involving concept-attainment was the subject investigations by Bruner, Goodnow, and Austin (1956). Their studies indicated that individuals were markedly consistent from one task of concept-attainment to another similar task. Eifermann (1965) also observed that most subjects were consistent in their patterns after the first task. Eifermann (1965) uses the terms component-centered and concept-centered to identify the patterns. Bruner and others (1956) used the terms focussing and scanning to identify similar type patterns. Focussing was defined as the use of a positive instance as a focus followed by testing of the attributes of this instance. Scanning was defined as the testing of hypothesis or concepts.

In these studies, the choice of an instance permitted the subject to view all of the attributes of that instance. The subject could select different attributes by going from instance to instance. In the present study, the subject was required to select both individual instances and attributes which he wished to view. The subject was told which instances were positive. It would seem that a subject who followed a "focussing strategy" would select a pattern of only positive instance. Wetherich (1964) identifies the selection in a problem in forming a concept of only positive instances from the field of instances as an "analytic" strategy. The selection of of positive and negative instances from the entire field he calls "global". Wetherick relates these two strategies to focussing and scanning respectively. The terms analytic and global are related to the psychological terms "field independent" and "field dependent". Witkin and others (1962) identify these terms as representative of two "cognitive styles". Cognitive styles are the "characteristic self-consistent ways of functioning by the person in the cognitive sphere" (Witkin, 1962, p.72). Witkin (1964, p.35) describes the "field dependent-independent" style in terms of personal experience.

> The person with a more field independent way of perceiving tends to experience his surroundings analytically with objects experienced as discrete from their backgrounds. The person with a more field dependent way of perceiving tends to experience his surroundings as a relatively global fashion passively conforming to the influence of the prevailing field or context.

Witkin (1962) relates the field independent-dependent cognitive style to perception. When this style is applied to problem-solving or concept-formation, Witkin indicates that the use of different but closely related terms are required. He chose analytic and global which later were used by Wetherick as indicated. The choice of these two terms for the present study is made since the analytic solver may select attributes from only the positive instances independent of the field of instances, i.e. without viewing any attributes of the negative instances. The global solver would view negative instances even though these instances provide no relevant information. In the tasks as designed, only positive instances were required to determine the correct answer, and thus focussing would seem to be the most efficient strategy. In the present tasks, subjects who were analytic might select the values of all attributes of one positive instance, or they might select the values of one attribute on the two positive instances. These might be assumed to be two different patterns and were identified as "instance-centered analytic" and "attribute-centered analytic" respectively. Subjects who were global might be considered as those subjects who viewed all instances, including negative as well as positive instances. As with the analytic subject, global subjects might choose to make selections along one instance or along one attribute, thus two terms were used for these patterns, "instance-centered global" and "attribute-centered global".

In order to differentiate between patterns of analytic and global, the percentage of the selections made which were from positive instances were used.

There have been many studies concerning the effect of positive and negative instances on the attainment of concepts. Bruner and others (1956) used the selection of positive instances as a criterion for assignment to the category of focussing. Other studies have indicated results which might be described as task dependent since varying results were obtained with varying tasks (Yudin and Kates, 1967; Kates and Yudin, 1968; Hovland and Weiss, 1957; Glanzer, Huttenlocher and Clark, 1963; and Klausmeier et. al., 1964).

The amount of information obtained by the subject prior to proposing a hypothesis has been included in pattern descriptions by Eifermann (1965) and Klausmeier and others (1964). The term "guess" was used by Eifermann and "sufficiency" by Klausmeier. The term sufficiency was used in this study to indicate that the subject had obtained enough information to make the correct response since even after sufficient information was obtained the subject may still have been guessing at the response. The number of selections which were made by the subject also may have been indicative of the thought processes of an individual and were studied. The time which the subject took between making selections and to decide enough information had been obtained also may be related to the processes used by the subject. The median time to make a correct selection for each task and the mean time for all selections and the indication that enough information had been obtained are the measures used.

Experimental Techniques

In most of the studies cited, the technique involved the presentation of an array or sequence of cards or diagrams to individual subjects. An experimenter or observer was required to carefully observe and record the choices made by the subject. This involves a good deal of time and concentration on the part of the experimenter.

Problems may arise when variations in task presentation occur due to different experimenters or differences in an experimenter's presentation. The computer on-line terminal provides excellent capabilities in collecting, recording, and storing response sequences of a large number of subjects, thereby reducing human recording and transcribing errors (Whittington, 1971; and Johnson, 1972).

Another advantage of computer useage is that "Computer management of procedure provides greater standardization of research" (Whittington, 1971, p.2). This greater standardization should reduce the error variance allowing better measurement of effects on the dependent variable (Johnson, 1967). However, Johnson.(1972) indicates that a computer administered task involves greater variance in subject performance than does a human experimenter administered task. Nevertheless, "it is a simple matter for a computer to simultaneously collect data or latency of response, type of response, amplitude of response, physiological variables, etc., all with a high degree of accuracy and for more than one subject" (Ragsdale, 1966, p.3). When writing of the computer, Suppes (1968, p.92) states: "The difficulty of collecting an adequate amount of behavioral data on subject-matter learning is so great and the problem is so complex, that it is difficult to conceive of doing an adequate job with simpler apparatus."

The computer also should provide greater capabilities in using various materials in tasks involving the attainment of concepts. Most research on concept-learning has been done with simple concepts which are not similar to those which the subjects would encounter normally in their learning situations. Staats indicates that these "contrived" concepts, such as "three green triangles on a background of red" or "two blue circles with two borders around them", are not sufficient to provide necessary data on the learning of concepts and what is needed is the development of "methods of research and a research rationale that begin to deal experimentally with samples of actual cognitive development" (Staats, 1970, p.383). Johnson (1972) designed a task which would be challenging to the subjects, college students, in his experiment which involved the use of an on-line computer terminal. The tasks presented in the present study were very similar to a laboratory problem used in the Chemical Education Material Study curriculum materials (Malm, 1963, p.86). They also were meant to convey some realistic situations which might be applicable in solving a similar "real" problem. Several uses of the computer in presenting realistic laboratory simulations were described by Showalter (1970).

Thus the computer provides unique capabilities in reseach studies of actual cognitive development and provides "the technological capability for accomplishing a high degree of individualization in instruction" (Stolurow, 1968, p.116). Stolurow continues, "The problem now is to find the critical psychological and educational data which would make such a technological capability an effective means of instruction" (Stolurow, 1968, p.116). The study of subject patterns in tasks in attaining concepts, the relationship of these to individual characteristics, and the effects of task variations might provide such data.

Definition of Terms

Analytic--"tendency to experience items as discrete from an organized context" (Witkin, 1964, p.180). The choice of only positive instances with no negative instances.

Attribute--Discernible characteristic of an object, event, or idea that distinguishes it from other objects, events or ideas.

Attribute-centered--A pattern of selections in which the subject selects the values of one attribute for the instances considered and then selects the values of another attribute for the instances considered.

Attribute-identification--A conceptual problem in which the rule is known and the relevant attributes are to be identified.

Concept--"A concept exists whenever two or more distinguishable objects or events have been grouped or classified together and set apart from other objects on the basis of some common feature or property characteristics of each." (Bourne, 1966, p.3)

Concept-attainment--The process involved in using discriminable attributes of objects and events as a basis of anticipating their significant identity (Bruner, et. al., 1956, p.21).

Conceptual Rule--Statement which specifies how the relevant attributes are combined for use in classifying an instance.

Conceptual Rule--Statement which specifies how the relevant attributes are combined for use in classifying an instance.

Conjunctive Rule--The joint presence of the appropriate value of several attributes (Bruner et. al., 1956, p.41).

Focussing--The use of a positive instance as an initial point followed by selections to test the relevance of attributes.

Global--"A tendency to experience items as fused with context." (Witkin, 1964, p.180) The choice of instance from both positive and negative fields.

Instance--An object, event or idea which is presented as either being classified in the concept, a positive instance, or as not being in the concept, a negative instance.

Instance-centered--A pattern of selections in which the subject selects the attributes of one instance and then selects the attributes of another instance.

Irrelevant attributes--A characteristic of an instance which is not used in the classification of the instance to a concept.

(Present study)--Those attributes which do not have the same value for both positive instances.

Positive instance--Those stimuli which illustrate or exemplify the concept.

(Present study)--Those liquids which contain the unknown substance.

Relevant attribute--A characteristic of an instance used to classify the instance as a member of the concept.

Scanning--The total hypothesis or concept is considered in making selections.

Strategy--The process which the subject uses to obtain information in attaining a concept.

Pattern--The arrangement or sequences and type of selections made in attaining a concept.

Hypotheses

Methods to identify patterns present in the process by which individuals gather information while attaining concepts were studied. How certain changes in the tasks given to the subject affect these patterns also was examined in several ways. The sequence and type of selections made were considered the major components of these patterns.

Other performance measures related to these patterns also were taken as indicative of the processes used.

1) There are no significant differences between patterns of selections used by different individuals on similar tasks in the attaining of concepts.
2) There are no significant differences between the patterns used by an individual subject on similar tasks in the attaining of concepts.
3) There is no relationship between the patterns used by individuals and their sex, intelligence and major field of atudy.
4) There are no significant differences in patterns used by subjects when the characteristics of the tasks are changed with regard to organization of information in the instructions, organization of information in the tasks, difficulty of tasks and symbols used in the task.
5) There are no relationships between the selection characteristics (median selection time, number of selections, initial instnce), response characteristics (mean response time, sufficiency of information, correctness of response), and the patterns of selection (percentage of positive instances and sequences of selections).

Assumptions

1) Suitable programs can be developed which will be sensitive enough to differentiate patterns which different individuals use in completing tasks involving the attainment of concepts.
2) These programs can be administered by means of a IBM 2741 teletype computer terminal.

3) The study of these patterns will provide information concerning the conceptual strategies utilized in attaining concepts.
4) The random assignment of subjects to the various groups experimentally controls for various personality characteristics of the individuals and other biasing factors.
5) The tasks written require the subject to utilize skills in attaining concepts and that these skills are measured by the results of the task.

Limitations

1) The samples were taken from a rather narrow range of individuals, Ohio State University students in either elementary education or science education.
2) The use of the on-line computer terminal may limit findings to tasks performed on a terminal.

Delimitations

1) The task required no information from negative instances.
2) The universe of instances and concepts was limited.
3) Positive instances were positioned in second, third or fourth position in the matrix and never in the first position.
4) Only one conceptual rule, conjunctive, was used.
5) The science background or knowledge of materials similar to the tasks was not measured.

Description of Study

The study investigated patterns exhibited by individuals in the formation of concepts. The subjects were given three simulated experiments by means of a computer on-line terminal. In the first phase of the study, the performance of secondary science education and elementary education students on the tasks was investigated. The measures of performance on three similar tasks were analyzed with regard to variances between individuals as compared to variances within individuals. The relations of these measures to individual characteristics were computed. In the second phase of the study , the effect of changes in task characteristics on the performance of elementary education students taking the tasks was studied.

In order to determine which performance measures might provide relevant information as to individual processes, the literature related to the learning or formation of concepts was studied and reviewed.

CHAPTER II

REVIEW OF RELEVANT LITERATURE

Concept-formation or concept-learning has been the subject of study for at least fifty years (Fisher, 1915, and Hull, 1920). Several discussions of concept-formation and theories involved in cognitive processes also have been written. Among these are those of Brown and Archer (1956), Bower and Trabasso (1964), Melton (1964), Reitman (1965), Klausmeier and Harris (1966), Kleinmutz (1966), Pikas (1966), Kleinmutz (1967), Bourne (1970), and Polson and Dunham (1971). One of the first reviews of studies in concept-formation was that of Vinacke (1951). Since that time several reviews of the studies in this field have appeared, notably those by Bruner, Goodnow, and Austin (1956), Kendler (1961), Klausmeier, et. al. (1965), Bourne (1966), Glaser (1968), Clark (1971), and Bourne and Dominowski (1972). Bourne (1966) has classified these studies in two sections, "task variables" and "organismic variables"; the latter dealing with the individual involved in the formation of concepts. For the present study, organismic characteristics are further subdivided into performance and individual characteristics; the former dealing with the individuals performance on the tasks in forming concepts and the latter dealing with the characteristics which are evident in the individual prior to performance on the task.

Performance Characteristics

Of interest in this study was "the characteristic, self-consistent ways of functioning shown by the person in the cognitive sphere" which is called the "cognitive style" by Witkin (1964, p.172). Among the studies of "styles" in cognitive behavior are Bruner, Olver and Greenfield (1966), Coop and Sigel (1971), Gardner (1953), Gardner, et. al. (1959), Garrettson (1971), Harvey, Schroder and Hunt (1961), Kagan, Moss, and Sigel (1963), Ross (1965), Scheerer (1964), Shouksmith (1969, 1970), and Witkin et. al.(1962, 1967). Two studies refer to "sets" in cognitive behavior, Forehand (1962) and Gagne and Paradise (1961). Enough studies had been done by 1953 so that Smith (1953, p.213) continues "The findings justify the conclusion that stylistic consistencies inferred from serial patterns of cognitive behavior allow prediction of performance in a variety of cognitive situations." Among the more recent studies which deal with cognitive styles and the learning of concepts are Fredrick (1968), Hester and Tagatz (1971), Jacobson, Millham and Berger (1969), and Lee, Kagan and Rabson (1963). Bruner, Goodnow and Austin (1956) studied individual cognitive behavior as "strategies" in concept-formation.

Patterns

Strategies were defined by Bruner, Goodnow and Austin (1956) as the pattern of decisions made by the subject in solving problems in the attaining of concepts. These patterns were identified from the sequence of selections or examples used by the subject. These researchers identified four ideal selection strategies: simultaneous scanning, successive scanning, conservative focussing, and focus gambling. However, Bruner et. al. (1956) implied that simultaneous scanning was not observed in individual performance patterns. In the scanning strategies, the subject considered the entire group of possible hypotheses or concepts. In the focussing strategies, the subject used positive instance as a starting point and tested only those hypotheses which were tenable with this instance.

Utilizing a card choice problem similar to that of Bruner and his coworkers, Laughlin (1966, p.776) reported that "two strategies are empirically as well as theoretically distinguishable problem-solving processes." These selection strategies were identified as focussing and scanning. Others who have identified focussing and scanning strategies are Durell (1972), Giambra (1968, 1969a,b, 1971a,b), Kates and Yudin (1964) and Tagatz (1967).

Wetherick (1966) developed a different type of problem involving the identification of the relevant attributes. In a later study, Wetherick (1969) used this problem to identify focussers and scanners. Most subjects were identified as scanners but focussers were more efficient in the experimental situation. Wetherick concluded that in "real" situations the problem solver had to decide which aspects of the problem to study leading the individual to scan all possibilities. In the experimental situation, the subject was able to focus since "the relevant dimensions of variations are specified either implicity or explicity" (Wetherick, 1969, p.7).

Another investigator who categorized observed strategies in two terms is Eifermann (1965). These were named component-centered, focussing on the attributes of the instances, and concept-centered, looking at the concept as a whole. Byers (1963), however, abandoned

Bruner's ideal strategies and indicated that all subjects utilize only attributes and thus might be classified in only one category, focussers. He utilized a task in the attainment of a concept which involved seven attributes and identified different strategies on the basis of the number of attributes changed from one instance to the next. Most subjects were found to be consistent in their strategies, changing the same number of attributes from one instance to the next. Klausmeier, Harris and Wierms (1964) revised this classification scheme into two categories, conservative and gambling. Conservative strategies were those in which the subject did test all attributes before proposing an hypothesis as to the concept represented. Gambling strategies were those in which the subject did not test all attributes before proposing an hypothesis.

Witkin (1964) described two strategies, global and analytic, which he related to the psychological constructs field-dependent and field-independent. The global strategy was identified by the subject utilizing the entire field of instances or concepts. The analytic strategy was identified by the subject selecting only certain attributes of the instances or only certain instances. Witkin (1964, p.180) adopted "the designation analytic-global field approach to represent this broader dimension of cognitive functioning, involving at one extreme a tendency to experience items as discrete from an organized context, and at the other extreme a tendency to experience items as fused with context." Wickelgren (1964) used these two strategies in a study of concept-formation and relates global to scanning strategies and analytic to focussing strategies. Davis and Klausmeier (1970), Fredrick (1968), and Kirschenbaum (1969) identified these strategies in patterns used by subjects in attaining concepts. Hester and Tagatz (1971) used "instructional strategies" which they called "conservative" and "commonality" and related these to analytic and global strategies. These strategies were earlier identified by Tagatz (1967) and with others (1969). The "commonality instructional strategy" did not require discriminations within the stimulus field while the "conservative instructional strategy" required the subject to selectively choose only certain stimuli from the field of stimuli. Many studies seemed to identify individual differences on the basis of completeness of their selections from the field of instances. In the present study, the terms analytic and global were chosen to indicate the patterns identified. Analytic implies an obvious selection which may be more efficient; thus, those subjects who select only positive instances, the only instances necessary for correct solution, were identified as analytic. Global implies a general view of the total field; thus those who select both positive and negative instances were identified as global.

Gumer and Levine (1971) found that students chose to select instances which provided information along one dimension (attributes) before changing dimensions. This "dimensionality", however, was limited in the sense that subjects were required to select "entire" instances to obtain the value for a given attribute. It might be that given the choice of selecting all attributes of one instance separately may be a different dimensionality than selecting one and only one attribute for each instance. In the present study, the subject was given that choice and was identified as attribute-centered or instance-centered depending upon the choice of selecting the values for <u>one</u> attribute across instances or the values of the attributes for <u>one</u> instance.

Positive and Negative Instances

Wetherick (1966) defined a different kind of strategy based on the use of positive and negative instances. A mixed strategy was one in which the subject eliminated those sets of attributes which were present in both positive and negative instances. A positive strategy was one in which the subject eliminated those sets of attributes which were not present in every positive instance. Braley (1963) discounted the use of negative instances, however, in excluding possible hypothesis indicating a low probability of this occurring. Several studies have indicated that positive instances provide more information than negative instances (Haygood and Devine, 1967, Haygood and Stevenson, 1967, Hovland and Weiss, 1957, and Glanzer, Huttenlocher and Clark, 1963). This seems particularly evident in conjunctive rules in which Taplin (1971) found that negative instances retard performance. He also reported that better performers chose a higher proportion of positive instances than do poor performers on concept attainment tasks. However, other results have been reported. When an equal number of positive and negative instances were given conjunctive rules were learned faster than when the instances were in their naturally occurring ratio (Denney, 1969). Other investigators have found no significant differences between the use of positive and negative instances, if equal information was available from both types (Kates and Yudin, 1964, Yudin and Kates, 1963, and Kurtz and Hovland, 1956). Freibergs and Tulving (1962) found that subjects performed much better on conjunctive tasks with positive instances than with negative instances on first attempts. With practice, however, the difference became much less but subjects still performed somewhat better with positive than negative instances. Bourne and Guy (1968) found that in attribute identification, subjects performed best when instances were selected from the larger class of positive or negative instances. Klausmeier, Harris, and Wiersma (1964) report that negative instances in their selection tasks provide more information than did the positive instances.

Thus it appears that in different situations positive and negative instances provide various effects. In the task in the present study, only positive instances were required to obtain sufficient information to correctly identify the relevant attributes. Since negative instances contain no relevant information, it was most efficient to utilize only positive instances. In the words of Bourne, Ekstrand, and Montgomery (1969, p.593): "For conjunctives, positive instances are more informative, so that a high selection rate for positive instances is better regardless of other considerations". "Regardless" seemed somewhat strong in view of some of the other studies, and thus some other "considerations" with regard to subject performance were included.

Other Performance Measures

In studying overall performance on concept-formation tasks, three measures which have been used were number of responses, number of selections (Bruner, Goodnow and Austin, 1956, Laughlin, 1964, 1965, 1966, Laughlin and Jordan, 1967), and time to solution (Klausmeier, et. al., 1964, Shephard, et. al., 1961, and Byers, 1963). Bourne (1966) indicates that: "All three provide essentially the same performance index". This was indicated further in that "it is almost always the case that these measures are affected in the same way by important independent variables of experiment" (Bourne, 1966, p.46). In the present study, the subject's first answer was taken as the response for the task and thus the number of responses was eliminated as a performance measure. The other two measures were used with one attribute of one instance counted as one selection. Time was measured both with respect to correct selections and to all responses given by the subject during the information gathering phase. Another measure of over-all performance of subjects was whether the problem was solved correctly or not (Klausmeier, et. al., 1964). These over all performance measures provide "little or no detailed information on how the subject attains solution" (Bourne, 1966, p.46). For this information, the patterns of selections were examined. The performance characteristics were observed during a specific task. Other characteristics were not related to a task but rather to the condition of the individual prior to the task.

Individual Characteristics

Among the characteristics of the individual which have been studied with regard to the learning of concepts that are not task related are major field of specialization, sex, and intelligence.

Major Field of Specialization

The one report of the effect of major field of specialization contains conflicting evidence (Klausmeier, Harris and Wiersma, 1964). Using a small number of subjects with the instructions read to the subject, the following results were reported: Home Economics, Speech, and Foreign Language majors were most efficient with respect to a concept learning task, while Science, Mathematics and History majors were intermediate, and Agriculture, English and Physical Education (men) majors were least efficient. A later study, included in the same report (Klausmeier, et. al., 1964), found no significant differences with respect to major fields. The later study had a larger number of subjects and was different in that the instructions were read by the subjects and the material itself was different.

Sex

Giambra (1968), Pishkin, Wolfgang and Rasmussen (1967), Pishkin and Rosenbluh (1966), Staudenmayer and Schvanaveldt (1971), Klausmeier, Harris and Wiersma (1964), Fredrick (1968), Fredrick and Klausmeier (1965) report no significant differences between college age males and females on concept learning tasks. Tagatz (1967) found no differences due to sex in elementary school children performing a concept attainment task. However, Dale (1970) in a repeat of Piaget's first chemical problem (Inhelder and Piaget, 1958) found a difference in methods of solution between girls and boys. Olson (1963) found that high school sophomores also varied in their performance on a task in attaining concepts depending on their sex. Thus differences on such tasks in college students appear not to be significant with some possible difference due to sex in younger students in learning concepts.

Intelligence

"It seems only natural that intelligence and the ability to solve conceptual problems should be strongly related" (Bourne, 1966, p.89). This relationship was reported by Rooze (1969), Denny (1966), and Mazzei and Goulet (1969). Klausmeier, Harris and Wiersma (1964) found that subjects who solved concept attainment tasks correctly took less time than those subjects who answered incorrectly. It might be inferred that those subjects capable of reaching a correct conclusion probably are more 'intelligent' than those unable or unwilling to reach a correct conclusion. If this is true, it might imply that more intelligent, successful, subjects utilize less time to solve a concept attainment task than less intelligent, unsuccessful, subjects. Schneider and Giambra (1971) found no significant correlation between American College Test scores and performance on tasks in formation of concepts. The American College Test (ACT) scores correlate with Wechsler Adult Intelligence Scale (WAIS) and college grade point average at about the .60 level (Severinsin, 1965). In a series of three studies (Osler and Fivel, 1961, Osler and Trautman, 1961, and Osler and Weiss, 1962), Osler and coworkers investigated the effects of IQ on concept attainment. With general instructions, subjects with high intelligence were apparently able to define the problem and then solve the problem more rapidly than subjects with average intelligence. With specific instructions which more clearly defined the problem, there was no significant differences between the performances of the two groups at different levels of intelligence. Wolff (1967) repeated the study but did not get replicate results; instead, he found that intelligence is related to concept attainment. Millham (1971) seems to summarize most of the results with regard to intelligence and individual characteristics in general, when he views them as "subject factors that generate differential responsiveness to situational and task variables."

Task Characteristics

Among the situational or task characteristics which have been studied in concept formation are the effect of instructions, practice tasks, stimuli organization, memory requirements, and difficulty of task.

Instructions

There is a good deal of reported variation in the effect of instructions on concept formation tasks. However, a good deal of variation exists in the different forms of instructions used. Archer, Bourne and Brown (1955) and Fredrick and Klausmeier (1965) found no significant differences due to instructions while Lynch (1966) reports a significant difference in performance when the subjects are given complete information concerning the task as opposed to incomplete information. Denney (1969) reported that subjects given both positive and negative instances as examples in the instructions performed less well than those simply given positive examples. Laughlin (1968) based his change in instructions on the directions given to the subject regarding the rate at which they were to solve the problem. One group received instructions to complete the problem in the fastest possible time, while the other group was told to complete the problem with the fewest possible selections. No significant differences were found between the two groups in the number of selections made, but the group instructed to proceed as fast as possible used significantly less time than the group instructed to use the lowest number of selections possible. Jolly (1970) instructed some subjects on a focussing strategy and others on a scanning strategy. Those instructed to use the focussing strategy performed better than those using the scanning strategy. Pyle (1970) reported that giving maximum amount of information in the instructions facilitated the rate of learning but any lesser amount did not. Osler and Weiss (1962) investigated the interaction of IQ and instructions by giving specific instructions on the method by which a concept attainment problem should be solved to one group, while giving only general instructions to another group. No significant difference was found between subjects with average IQ and those with high IQ when specific instructions were given. However, the high IQ subjects performed better than the average IQ subjects when general instructions were given.

Practice Tasks

A different aspect of instructions is the effect of practice or sample tasks. Olson (1963) found that the effect of practice on performance in concept attainment tasks lasted for only the first task in a series of tasks. Laughlin (1971) found that there was a significant improvement after the first task but no differences were found between two and three. White, Richards and Reynolds (1971) found an inverse relationship between the number of pretaining problems, from none to three, and the number of selections made to completion of a concept identification task. In the present study, one sample task was presented to the subject, followed by three actual tasks. Slaymaker and Nahinsky (1969) found that test trial stimuli had no effect on hypothesis sampling behavior identifying conjunctive concepts.

Stimuli Organization

The organization of the sample task in the present study was varied. Most studies, however, vary the stimuli organization in the task to study the effect. Bruner, Austin and Goodnow (1956) studied the effect of presenting an ordered display versus a random display. A display in which the attributes of the instances were obviously in an arranged order significantly decreased the number of trials to learn a concept when compared to a random arrangement. The difference in arrangement also changed the strategy used by the subjects. The strategy of less risk, focussing, was used more often with an ordered display than with an ordered display than with a random display,while the occurrence of scanning was greater with a random display than with an ordered display. Klausmeier, Harris and Wiersma (1964) also indicate that whether a display is random or ordered affects the strategies used by subjects. The random display invokes more "gambling" or guessing on the part of the subject than does an ordered display. However, Huang (1971) indicates that a random display "forces" the subject to use other strategies than focussing, the strategy identified as most often used with a systematic arrangement. These studies indicate a facilitating effect of systematic or ordered displays on concept attainment tasks. However, Laughlin (1964, 1965) in two different reports, found no significant difference between an ordered display and a random display in a selection task.

A different form of organization was studied by Shephard, Hovland and Jenkins (1961). They studied compact displays, in which all attributes of an instance may be viewed simultaneously, and distributed displays, in which the attributes of an instance are separated across the display. Subjects performed the concept attainment tasks more quickly and accurately with compact displays than with distributed displays. These results also were reported by Bourne and Parker (1964) and Slaymaker (1972). This effect, similar to the effect of random versus ordered displays, may be due to either the "forcing of the subject" to view the individual attributes in the distributed display, or it might be due to the extent of memory required.

Memory Requirements

The effect of memory requirements on performance in concept attainment tasks has been studied by Bourne, Ekstrand and Montgomery (1969). "The necessity to remember at least some portion of the information provided by preceding events...might induce (the subject) to adopt a strategy, such as conservative focusing, which minimizes the memory requirements of the task" (Bourne, Ekstrand and Montgomery, 1969, p.543). In an earlier study, Bourne, Goldstein and Link (1964) conclude that "only a small percentage of errors in concept learning is attributable to subject's failure to draw appropriate inferences from perceptually available information" (Bourne, Goldstein and Link, 1964, p.445). Laughlin (1968) indicates that memory effects may be limited to receptive tasks. In a review of studies dealing with the role of memory in concept learning, Dominowski states that: "performance is generally improved by increasing the availability of previous stimulus information" (Dominowski, 1965, p.271). Also Glanzer, Huttenlocher and Clark (1963), Pishkin and Wolfgang (1967), Kates and Yudin (1963), and Cahill and Hovland (1960) indicated that allowing all instances, once exposed to remain in view produced much better performance in concept learning than when each instance is removed from view before the next instance is viewed. Laughlin (1969) utilized a system to study memory effects in which an array of instances was presented to the subject. As each instance was selected, the subject moved the instance to appropriate areas depending on whether the instance was positive or negative, or the subject left the instance in the array depending on the treatment group. Those subjects who were provided with a means of perceptually organizing the instances already chosen took a significantly fewer number of choices to learn the concept than those with no perceptual organization.

Difficulty of Task

In addition to the perceptual organization or availability of stimuli, conceptual differences are also produced by the difficulty of the task. The role of conceptual or cognitive organizers in facilitating concept learning in elementary school science was reported by Schulz (1967) as being interactive with subject skills. Using advance organizers, as defined by Ausubel (1960), he reported that these organizers seem to facilitate learning only when subjects lack certain processing skills related to analytic ability. More irrelevant attributes are reported as increasing the difficulty of the task (Bourne, 1957, Bourne and Haygood, 1960, Rabinowitz and Beaton, 1971, Rasmussen and Archer, 1961, Scandura and Voorhies, 1971, and Walker and Bourne, 1961). An increase in the number of values for each attribute are reported as increasing the difficulty of the task (Archer, Bourne and Brown, 1955, and Gelfand, 1958) or causing no differences (Slaymaker and Nahinsky, 1969). Laughlin (1971) attempts to explain some of these contradictory results from his study which indicated a curvilinear relationship from total relevant to total irrelevant with total amount of information constant. He concludes that most of the differences in the studies reported above are due to differences in the amount of information rather than differences in the number of relevant or irrelevant attributes.

Of the rules defined by Haygood and Bourne (1965), the conjunctive rule is reported as the easiest in tasks using the reception paradigm (Conant and Trabasso, 1964, Laughlin,1969, Laughlin and

Jordan, 1967, Schwartz, 1966, and Namikas and Carey, 1971) and in the selection paradigm (A. Miller, 1971). In a different type of study, Huttenlocher (1962) found that "manipulation" of attributes in a task in formation of concepts increased the difficulty of the task. This raised the question of manipulation as a conceptual process with respect to the computer administered task which requires individual "manipulation" of attributes.

CHAPTER III

METHODS AND PROCEDURES

In the process of learning science concepts, the steps taken by an individual in attaining the concept should provide information useful in preparing instructional programs meant to meet individual differences. A task was developed to be used in the investigation of strategies used by individuals in attaining a concept. A computer program was used to present the task by means of an IBM 2741 terminal. Johnson (1966) has shown that a computer can be used in presenting a complex problem-solving task.

The study was designed in two phases. Phase I utilizes subjects from secondary and elementary teacher education in order to identify individual differences used in attaining concepts. Phase II utilizes subjects from elementary education only and provides information concerning the relationship of task characteristics to the formation of concepts.

Tasks

Tasks were developed similar to one given in the Chemical Education Material Study Manual as Experiment 33 (Malm, 1963, p.86). This experiment involved the formation of a single chemical analysis scheme. The results of mixing different chemicals were used to detect the presence of an unknown substance. In the present study, the reactions between the liquids and test solutions were simulated.

These reactions were used to determine which tests were necessary to identify the presence of an unknown substance or contamination.

The tasks were attribute identification task composed of four instances, two of which were positive or contained the unknown substance and two negative or did not contain the substance. In all instances, two attributes were required to indicate the presence of the unknown. The rule defining the concept was conjunctive. The universe of possible instances consisted of eight different combinations of precipitate (P) and no precipitate (N) on each of the three attributes. These are given in Table 1.

TABLE 1.--Universe of Possible Instances for Selected Tasks

		Instances							
		A	B	C	D	E	F	G	H
	1	P[a]	P	P	N	N	N	P	N
Attributes	2	P	P	N	P	N	P	N	N
	3	P	N	P	P	P	N	N	N

[a] P = precipitate; N = No precipitate.

Given that there were two relevant attributes, three combinations of attributes was possible, 1 and 2; 1 and 3; and 2 and 3. For each of these combinations, four pairs of instances had the same values for the relevant attributes and a different value for the irrelevant attribute. If 1 and 2 were selected as the relevant attribute, the four possible pairs of instances are given in Table 2. Similar results were possible for the other combinations of relevant attributes.

In order to provide equivalent amounts of information with each

TABLE 2.--Possible Pairs of Positive Instances with 1 and 2 as Relevant Attributes

		Pairs of Instances							
		C and G		D and F		A and B		E and H	
Attributes	1	P	P	N	N	P	P	N	N
	2	N	N	P	P	P	P	N	N
	3	P	N	P	N	P	N	P	N

attribute, the value for each attribute in three of the four instances was the same. This reduced the possible pairs of instances which might be used as negative instances to two. If C and G was chosen as the pair of positive instances, B and H and A and E were the two possible pairs of negative instances. The combinations of two positive and two negative instances with attributes 1 and 2 relevant are given in Table 3.

TABLE 3.--Possible Combinations of Four Instances for Use in Task

		Negative Instances		Positive Instances		Positive Instances		Negative Instances	
		B	H	C	G	C	G	A	E
Attributes	1	P	N	P	P	P	P	P	N
	2	P	N	N	N	N	N	P	N
	3	N	N	P	N	P	N	P	P

Development of Program

The program was developed during the academic year 1971-1972. The schedule used in the study is given in Table 4.

Pilot Studies

The preliminary program, consisting of one task, was given to

TABLE 4.--Calendar of Program Development and Administration

<u>Autumn 1971</u>

Preliminary Writing
Pilot Study with Graduate Seminar

<u>Winter 1972</u>

Extensive Revision and Expansion
Pilot Study with Senior Secondary Science Education Students

Minor Revision

<u>Spring 1972</u>

Pilot study with Secondary Science Education Students

Phase I	Phase II
With Junior Secondary Science and Elementary Education Students	With Elementary Education Students

fifteen science or mathematics education graduate students in a seminar on educational research. The instructions, sample task and the information during the solving of the tasks were given as shown in Table 5.

TABLE 5.--Instructions, Matrix Sample Task and Linear Experimental Task as Given to Subjects

```
Welcome to a computer simulation laboratory.
We will be working with variousliquids and tests,
imaginary of course, which you may mix andobserve
the resulting reactions. Have you used a computer terminal
before? The machine typing this is a terminal.
Type either yes or no and then press theRETURN key.

yes

Fine, let's go on to the activity.


     This activity presents three tasks.For each task:

Problem:
Determine tests for identifying contaminated water.

Materials available:
3 tests
4 samples of water, 2of which are specifiedas contaminated.
```

TABLE 5.--Continued.

Conditions in our "lab":
1) No test gives the same result with all 4 samples.
2) An identifying test gives the same result with each contaminated sample.
3) Uncontaminated samples may not be identical.
4) More than one test may be necessary for the identification.
5) Only one test can be requested for one sample at a time.

EXAMPLE:

Suppose you were given four liquids, A, B, C, and D, with liquids A and C containing a substance for which you want to find the tests which would identify it. You are given tests 1, 2, and 3 to work with. You can request test results, one at a time, such as test 2 on liquid C (by typing c2) OR test 1 on liquid D (by typing d1).

Try requesting the result of test 3 on liquid C.

c3

Precipitate

Good.

If you had requested, for the EXAMPLE problem, all three tests on all four liquids, one of each at a time:

The following matrix represents the results you might get.

		Liquids			
		A	B	C	D
	1	No Pre	No Pre	No Pre	Precip
TESTS	2	No Pre	Precip	Precip	Precip
	3	Precip	No Pre	Precip	Precip

Which test or tests do you think can be used to identify the substance. Type the number or numbers of the test or tests, if more than one test, put a & sign between the tests, for example, 1&2&3.

1&2

Fine, your answer does compute, but the correct response was 1&3.

Test 2 produces different results in the two liquids that contain the substance and cannot be used to identify it, at least not in our "lab".

Test 1 produces the same result in liquid B, which does not contain the contamination, as in the two liquids, A and C, which do contain the contamination. Therefore test 1 can not be used by itself to identify the contaminated liquids.

TABLE 5.--Continued.

Test 3 produces the same result in liquid D, which does not contain the contamination, as in the two liquids, A and C, which do contain the contamination. Therefore test 3 can not be used by itself to identify the contaminated liquids.

The combination of BOTH contaminated liquids producing the same result, in this case a precipitate, with test 3 and BOTH producing the same result, no precipitate, with test 1 is required to identify liquids A and C which contain the substance as being different from liquids B and D which do not contain the substance.

NOW ON TO THE PROBLEMS

Each problem will require that you request a new set of results of the tests on the liquids in each new problem BEFORE typing ready, which is your signal to the computer that you know which test or tests can be used to indicate the presence of a contaminating substance and that you are ready to identify these for the problem.

Press the RETURN key to proceed to the first problem.

This problem has two tests which are necessary to identify the substance.
You are given four liquids, A, B, C, and D.
Liquids B and D contain the substance in this task.
The tests you have available are tests 1, 2 and 3.
When you are ready to identify which test or tests can indicate contamination, type ready.
Type the letter of one liquid and then the number of one test for each request.
Now press the RETURN key and then proceed with your request.

a2

No precipitate

b2

Precipitate

c1

No precipitate

d2

Precipitate

ready

The program was increased to include three tasks and different presentations of both the sample task and the tasks which the subjects were given. In addition to the matrix form given in Table 4, the sample task was programmed in a linear form as shown in Table 6.

TABLE 6.--Linear Presentation of Sample Task in Instructions

The following list represents the results you <u>might</u> get.

d1 produces a precipitate
a3 produces a precipitate
b1 produces no precipitate
b2 produces a precipitate
b3 produces no precipitate
a1 produces no precipitate
c1 produces no precipitate
d2 produces a precipitate
c2 produces a precipitate
c3 produces a precipitate
a2 produces no precipitate
d3 produces a precipitate

Which test or tests do you think canbe used to identify the substance. Type the number or numbers of the test or tests, if more than one test, put a & sign between the tests, for example, 1&2&3.

The information which some subjects received while solving the tasks was programmed in a matrix form, as shown in Table 7.

Three similar tasks were selected randomly from the possible combinations of instances, as identified on pages 35 and 36. The program programming of these three tasks, identified as A, B and C, was done exactly the same.

The three tasks were given to each of the members of the senior project in secondary science teacher education. The results were analyzed to determine if sufficient basis existed for the identification

TABLE 7.--Example of Matrix Presentation of Informational Feedback during Task

```
This problem has two tests which are necessary
to identify the substance.
You are given four liquids, A, B, C, and D.
Liquids B and D contain the substance in this task.
The tests you have available are tests 1, 2 and 3.
When you are ready to identify which test or tests can
indicate contamination, type ready.
Type the letter of one liquid and then the number of one
test for each request.
Now press the RETURN key and then proceed with your request.


b1

    A   B   C   D
1       No
2
3

d1

    A   B   C   D
1       No      Pr
2
3

c3

    A   B   C   D
1       No      Pr
2
3           No

a1

    A   B   C   D
1   No  No      Pr
2
3           No

ready

Type the test or tests which you feel are necessary to identify
the substance.
2&3

How about that? You are right.
```

of patterns which subjects use consistently and which are different from subject to subject. An analysis of variance program, BMDO2V, was used to compute variance due to the task and those due to individuals. The two measures were the percentage of positive instances used and the sequence of selections. The results for these analyses are summarized in Table 8.

TABLE 8.--Individual by Task Two-way Analysis of Variance of Percentage of Positive Instances and Sequence of Selections
Pilot Study with Juniors and Seniors in Secondary Science Education

	Source of Variation	df	Mean Sq.	F
Percentage of Positive Instances	Individuals	23	1726	5.77***
	Tasks	2	926	3.10[a]
	Residuals	46	299	
	Total	71		
Sequence of Selections	Individuals	23	20806	5.72***
	Tasks	2	225	11.73***
	Residuals	46	3640	
	Total	71		

*** Significant at the .001 level.

a Critical value at the .001 level for $F(2,40) = 8.25$.
Critical value at the .05 level for $F(2,40) = 3.20$.

Three subjects in this group did not follow instructions and did not make correct selections. Minor revisions were made in the program before the quarter in which the experimental study was done. To check these revisions and the various presentations, eleven students in a secondary science teaching methods course were given the program with the possible variations considered. All subjects followed the instructions correctly on the second and third tasks presented, although two subjects did not follow the instructions correctly for the first task attempted.

Following the pilot studies, the experimental study was conducted in two simultaneous phases.

Phase I

Population and Sampling

The groups in Phase I of this study were made up of all thirty-seven students enrolled in the junior year of the teacher education program in secondary science education and a sample of forty-eight students randomly selected from those enrolled in the elementary education science methods course at The Ohio State University, Spring Quarter, 1972. Half of each of these two samples were assigned randomly to one of two treatment groups. Four subjects in the elementary education course did not attempt the program. One secondary science and five elementary education students were unable to complete the program due to mechanical difficulties with the computer terminal. The distribution of subjects is given in Table 9.

TABLE 9.--Major by Treatment Group Distribution of Subjects in Initial Sample and of Subjects who Received the Instructions in the Program Phase I Elementary and Secondary Science Education Majors

	Major			
	Elementary Education Treatment Group		Secondary Science Education Treatment Group	
	1	2	1	2
Initial Sample	24	24	20	17
Did not attempt the Program	0	4	0	0
Mechanical Difficulties	3	2	1	0
Received Instructions	21	18	19	17

Treatments

The two treatment groups differed in the manner in which the information was presented following the subject's selection. One treatment involved a linear format for the presentation as in Table 5. The other treatment presented the information in a matrix form as in Table 7.

Variables

In addition to the task characteristics identified earlier, the dependent variables in Phase I were three individual characteristics, sex, major and intelligence as measured by the American College Test (ACT). Major was identified as elementary teacher education, coded as 1, or secondary science teacher education, coded as 2. The percentile scores for the ACT were obtained from the student records for twenty-two secondary education and twenty-nine elementary education students. Transfer students were not required to provide ACT scores.

The dependent variables for this study were:

Number of Selections (# S): The number of selections made according to the instructions for each task was recorded.

Percentage of Selections from Positive Instances (% +): The percentage of the selections made for each task which were from positive instances was computed with a possible range of 0, no selections from positive instances, to 99, all selections from positive instances. Fifty percent of the positive selections were positive.

Initial Instance (I I): The first selection made for each task was recorded as being from a negative instance, coded 0, or a positive instance, coded 1. No positive instance was presented in the first position. Thus no positive instance was identified with an A or a 1. This was to prevent the natural selection of one of these labels first from biasing the variable.

Median Selection Time (MdT): The median time interval was computed from the selection time intervals and the decision time interval. The selection time was computed in seconds from the time the indication was given by the computer that the subject could enter a request to the time the subject indicated he had completed the request by pressing the return key on the terminal. Only valid requests according to the instructions were included. The decision time was taken as the time interval between the time the information was given for the last selection made and the time the subject completed typing ready. Typing ready indicated the subject was ready to proceed with the identification of which test solutions were necessary for the determination of the presence of the unknown substance. For all subjects who followed instructions, the median time interval was within the range of selection time intervals. The lowest number of selections made was two and in this case, with the decision time included, the median time was one of the two selection times.

Mean Request Time (MnT): The mean request time was the mean value for all time intervals, correct selections, incorrect selections and decision to proceed to the next section. This time differs from the median selection time in that incorrect selections, those not made according to instructions, were included. Also, a large difference in decision time from selection time would influence the mean value much more than the median value, the mean value possibly occuring outside the range of selection times. The time was recorded in seconds.

Correctness of Subject's Hypothesis (Cor): The subject's hypothesis, with regard to which test solutions were necessary to indicate the presence of the unknown was identified as incorrect, coded 0, or correct, coded 1, dependent upon a match or no match with the unique programmed correct hypothesis. Two and only two test solutions were necessary according to the instructions to the tasks.

Sufficiency of Information (Suf): The sufficiency of the information obtained by the subject was taken as any amount of information corresponding to or greater than the minimal requirement for determining the correct hypothesis. The subject was informed that no attribute has the same value across all instances. In the terms of Bruner and others (1956), the irrelevant attribute was "noisy" rather than "quiet". Thus only the attributes of the positive instances are required for identification of the relevant attributes. All attributes with the same value for both positive instances were relevant. All irrelevant attributes must have different values for the positive instances.

Sequence of Selections (Seq): The sequences of selections were classified with respect to the terms, attribute-centered and instance-centered. The sequences were identified using the "move" from one selection to the next. A move from one attribute of an instance to a different attribute of the same instance was called an instance-centered move and represented as A1-A2. A move from one attribute of an instance to the same attribute of a different instance was called an attribute-centered move and represented as B1-C1. A move to a different attribute and a different instance was called a mixed move and represented as B1-C3. However, once a subject had made all selections in a given attribute or a given instance, the next move must be a change in attribute or instance even though the subject was consistently attribute-centered or ins instance-centered. Therefore, once an instance-centered subject had chosen three attributes in succession within one instance, the next move was considered neutral and not counted as a move. For example, an attribute-centered analytic subject would choose only two positive instances for each attribute and the next move to another attribute of a positive instance was considered neutral. An attribute-centered global subject would select the value of one attribute for all four instances and then the next move to another attribute would be considered neutral.

To quantify the information, instance-centered moves were assigned the value of 3, mixed moves 2, and attribute-centered moves were assigned the value of 1. Neutral moves were not counted as moves. Six examples of sequences, with numbers denoting attributes and letters denoting instances, are given in Table 10. Using the quantitative values assigned and dividing by the total number of moves provided a single number of moves provided a single number representative of the sequence of selections. If the interval from 100 to 300 is divided into three equal parts, all sequences with equalues to or below 167 were identified as attribute-centered. Sequences with values equal to or above 233 were identified as instance-centered and the sequences with values between 167 and 233 were identified as mixed.

To provide a measure of criterion referenced validity, the terms instance-centered, mixed and attribute-centered as applied to sequences of selections in solving the task were explained by the investigator to the graduate educational research seminar members.

TABLE 10.--Classifying Sequences of Selections According to Scoring System

Sequences	Sequence Name	Move Points	# of Moves	Score[a]
A1-A2-A3-C1-C2-C3 3 3 X 3 3	Instance-Centered	12	4	300
B2-B3-B1-D1-D2-D3 3 3 X 3 3	Instance-Centered	12	4	300
A1-B1-D1-C1-C2-D2-B2-A2 1 1 1 X 1 1 1	Attribute-Centered	6	6	100
D2-C2-B2-A2-A3-B3-C3 1 1 1 X 1 1	Attribute-Centered	5	5	100
A1-A2-B2-B3-C3-D2-D1 3 1 3 1 2 3	Mixed	13	6	217
C3-B2-A1-D1-C2-B3-A2 2 2 1 2 2 2	Mixed	11	6	187

[a] Score = (Move Points/Number of moves) X 100.

They were given the fifteen sequences of selections which had been obtained from the tasks for each of the subjects and asked to rate them in the appropriate categories. The sequences were scored on a scale of 100 to 300 by the investigator according to the system described. The mean values for the ratings of the subjects were correlated with the scores computed to give a criterion referenced measure of validity for the scoring system. The ratings and scores are given in Table 11.

Procedures

During the first two weeks of the Spring Quarter 1972, the investigator visited each section of the elementary education science methods course and each section of the junior project in secondary science education. Each student was given the two page handout

TABLE 11.--Mean Values for Ratings and Scores for Sequences of Selections on Preliminary Task

	Sequences														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Rating[a]	300	114	107	189	114	111	298	105	202	102	164	280	125	257	100
Score[a]	300	100	100	200	145	109	300	100	200	125	176	240	140	250	100

[a] Pearson R Correlation = .98; significant at the .001 level.

included as Appendix A and the general purpose of the program was outlined. The program was assigned as part of each of the courses. The students were instructed on the use of the computer terminal. All students in the secondary education course had previously used a terminal and only nine of the forty-four students in Phase I from the elementary education course had not used the terminal in other courses. The subjects were allowed to select the time which they would perform the task and asked to proceed with the task only when the terminal seemed to be operating properly. The latter precaution was stressed due to problems which had been evident with several typewriter terminals.

Experimental Design

The design of the study utilizes two treatment groups with repeated treatments and measures. The design was duplicated with two groups of subjects with different majors as shown in Table 12.

Data Processing Procedures

The computer program recorded student input from the on-line computer terminal and stored these on computer tape. Three different measures for each task were made available on punched data cards from the Computer-Assisted Instruction Center at The Ohio State University.

TABLE 12.--Experimental Design for Phase I

Majors	Treatment Groups	Tasks (X) and Performance Measures (O)					
Elementary	R_1	X_1	O_1	X_1	O_2	X_1	O_3
Education	R_2	X_2	O_1	X_2	O_2	X_2	O_3
Secondary Science	R_1	X_1	O_1	X_1	O_2	X_1	O_3
Education	R_2	X_2	O_1	X_2	O_2	X_2	O_3

These were 1) the number of selections, 2) the correctness of the hypothesis proposed by the subject, and 3) the selections made by each individual in the sequence in which they were made. The median selection time and mean request time for the selection sequence were provided by the CAI Center on computer printout sheets.

A program was written by the investigator which computed the percentage of positive instances and the quantitative value given the sequence of selections. Also included in this program was the identification of the initial instance selected as positive (1) or negative (0) and the sufficiency of information obtained prior to proposing an hypothesis, sufficient (1) and insufficient (0).

The data was analyzed at The Ohio State University Computer Center using Biomedical Computer Programs (Dixon, 1967) and MANOVA program distributed by Clyde Computing Service (Clyde, 1969).

Statistical Analysis and Design

The question of the relationships among the performance measures on the tasks and the characteristics of the individual was treated as a correlation problem. The correlations of the measures of dependent variables for each task with each other and with the measures of the independent variables were computed. The measures of the eight dependent variables for the second and third tasks and the measures of the four independent variables gave a twenty by twenty correlation matrix.

To determine consistency within individuals and differences between individuals in the patterns used with similar tasks, an analysis of variance design was used. A simple two factor analysis, with persons and tasks as the factors, was computed using the BMDO2V with the dependent variable sequence of selections and percentage of positive instances. For information as to the effect of major, treatment and task, a more complex design was used. The treatments and major of the subjects were used as factors with repeated measures across tasks. The design, shown in Table 13, corresponds closely to that of the three factor repeated measures design given by Winer (1971, p.560).

TABLE 13.--Schematic Design of Analysis of Variance Phase I

		Major			
		Elementary Ed. (M_1) Treatment Group		Secondary Ed. (M_2) Treatment Group	
		G_1	G_2	G_1	G_2
		P_{111}[a] ... P_{11n}	P_{121} ... P_{12n}	P_{211} ... P_{21n}	P_{221} ... P_{22n}
	1				
Tasks	2				
	3				

a P_{111} = First Person in M_1 and G_{11}.

The structural model for this design is given by Winer (1971, p.560) as having the following form:

$$X_{ijkm} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + \pi_{m(ij)} + \gamma_k + \alpha\gamma_{ik} + \beta\gamma_{ijk} + \pi\gamma_{km(ij)} + \varepsilon_{o(ijm)}$$

α = effect of Major
β = effect of Treatment group
π = Person effect
γ = Task effect

As an estimate of the variance for α, β and $\alpha\beta$, the variance of each term is combined with the error variance and the variance of $\gamma\pi$. Thus the "error term" for each of these three terms is the variance of ε plus the variance of $\gamma\pi$. A more complete description is given in Winer (1971, pp.560-572).

Phase II

Population and Sampling

The subjects in Phase II were the remaining one hundred sixty-six students in the elementary education science methods course. These students were assigned randomly to the eight treatment groups with a minimum of twenty subjects in each group. However, twelve subjects dropped the course before attempting the program and eight subjects were unable to complete the program due to mechanical difficulties with the computer terminal. The distribution of subjects is given in Table 14.

Treatments

Four task characteristics were changed to provide the various treatment groups. The possible combinations available with these changes are given in Table 15 and the treatments selected for this study are given in Table 16.

TABLE 14.--Treatment Group Distribution of Subjects in Initial Sample and of Subjects who Received the Instructions in the Program Phase II

	Treatment Groups 1	2	3	4	5	6	7	8
Initial Sample	21	23	22	19	19	22	20	19
Did not Attempt the Program	0	0	1	4	2	3	0	2
Mechanical Difficulties	0	1	1	1	3	2	0	0
Received Instructions	21	22	10	14	14	17	20	17

TABLE 15.--Possible Treatments

				Number of Relevant Attributes: Given		Not Given	
				Instances denoted by Letters	Numbers	Instances denoted by Letters	Numbers
Information in Experimental Task Presented	Linear Form	Sample Task Given In	Matrix	1[a]	2	4	5
			Linear	3	X[b]	6	X
	Matrix Form	Sample Task Given In	Matrix	7	X	8	X
			Linear	X	X	X	X

[a] Refers to Treatments used in the study.

[b] Refers to Treatments not used in the study.

TABLE 16.--Treatments Selected for Study

Treatment	Task Characteristics: Form in which the informational feedback is given to subject's Selections during Experimental Tasks	Form in which the Sample Task is presented	Symbols used for instances	Number of Relevant Attributes
1	Linear	Matrix	Letters	Given
2	Linear	Matrix	Numbers	Given
3	Linear	Linear	Letters	Given
4	Linear	Matrix	Letters	Not Given
5	Linear	Matrix	Numbers	Not Given
6	Linear	Linear	Letters	Not Given
7	Matrix	Matrix	Letters	Given
8	Matrix	Matrix	Letters	Not Given

An example of the matrix sample task is given in Table 5; of the linear sample in Table 6; of the linear experimental task in Table 5; of the matrix experimental task in Table 7. The distribution of the four variables in the eight treatments is given in Table 17.

TABLE 17.--Distribution of Task Characteristics in Treatment Groups

Task Characteristics	Treatment Groups 1	2	3	4	5	6	7	8
Matrix in Experimental Task	-[a]	-	-	-	-	-	+	+
Letters to denote Instances	+	-	+	+	-	+	+	+
Matrix in Sample Task	+	+	-	+	+	-	+	+
# of Relevant Attributes Given	+	+	+	-	-	-	+	-

[a] - indicates the absence of Task Characteristic; + the presence.

At least two treatments have one of the two values for each of the variables.

Variables

In addition to the task variables described in the previous section, two individual characteristics were selected as independent variables, sex and intelligence as measured by the ACT. Percentile scores were obtained for ninety-six subjects in Phase II.

The eight dependent variables described in Phase I also were used as criterion measures in Phase II.

Experimental Design

The experimental study consists of repeated treatments and performance measures within eight randomly assigned groups. The design is given in Table 18.

TABLE 18.--Experimental Design Phase II

Treatment Groups	Tasks (X) and Performance Measures (O)					
R_1	X_1	O_1	X_1	O_1	X_1	O_3
R_2	X_2	O_1	X_2	O_2	X_2	O_3
R_3	X_3	O_1	X_3	O_2	X_3	O_3
R_4	X_4	O_1	X_4	O_2	X_4	O_3
R_5	X_5	O_1	X_5	O_2	X_5	O_3
R_6	X_6	O_1	X_6	O_2	X_6	O_3
R_7	X_7	O_1	X_7	O_2	X_7	O_3
R_8	X_8	O_1	X_8	O_2	X_8	O_3

Procedures

The same procedures were followed with those students in Phase II as with the elementary education students in Phase I. These students were from the same sections as the students in Phase I. Phase I and Phase II were conducted simultaneously. Forty-seven of the one hundred fifty students in Phase II had not used the computer terminal previously.

Statistical Analysis and Design

The analysis of patterns and the effects of the treatment variables were assessed with an analysis of variance design given in Table 19.

TABLE 19.--Analysis of Variance Design for Phase II

		Treatment Groups							
		1	2	3	4	5	6	7	8
		$P_{11}-P_{1n}$	$P_{21}-P_{2n}$	$P_{31}-P_{3n}$	$P_{41}-P_{4n}$	$P_{51}-P_{5n}$	$P_{61}-P_{6n}$	$P_{71}-P_{7n}$	$P_{81}-P_{8n}$
	1								
Tasks	2								
	3								

The analysis model is similar to that given for Phase I except that the factors were only treatment group and person with repeated measures on tasks. The dependent variables and independent variables which were measures of individual characteristics were correlated as in Phase I.

CHAPTER IV

RESULTS OF THE STUDY

The results of this study are presented in two sections based on the two phases of the study. Phase I dealt with the determination of selection patterns used by individuals in solving a task of concept-attainment and with the relations between these patterns and other individual characteristics. Phase II dealt with the study of the effects of changes in the task characteristics on the subject's performance.

Phase I

Distribution of Subjects

Of the seventy-five subjects who received the instructions of the program, twenty-four subjects did not follow the instructions correctly. These subjects either typed no valid selections or did not make any selections before indicating they had obtained enough information to identify the necessary test solutions. The distribution of subjects who received the instructions and those who followed instructions and made valid selections is given in Table 20. Those subjects who followed instructions were assigned a value of 1 and those who did not a value of 0. This categorization resulted in a point-biserial correlation ($N = 30$) of .48, significant at the .01 level, with ACT scores and a phi coeffecient ($N = 51$) of .37, with major, significant at the .01 level.

The means of the ACT scores in each cell are given in Table 21 for those subjects for whom ACT scores were obtained. A two-way analysis

TABLE 20.--Major by Treatment Group Distribution of Subjects: Phase I Elementary and Secondary Science Education Majors

		All Subjects who Followed Instructions Treatment Group 1	2	Subjects who Followed Instructions Treatment Group 1	2
Major	Elementary Education	21	18	9	11
	Secondary Education	19	17	17	14

TABLE 21.--Major by Treatment Group Distribution of Mean Values of ACT Scores: Phase I-Elementary and Secondary Science Education Majors

		Subjects who received instructions Treatment Group 1	2	Subjects who followed instructions Treatment Group 1	2
Major	Elementary Education	34.85 N=13	34.54 N=13	39.25 N=4	43.71 N=7
	Secondary Education	59.25 N=12	70.75 N=12	66.90 N=10	83.22 N=9

of variance of ACT scores by treatment group and major was computed for each distribution. The results, given in Table 22, indicate that a significant difference in ACT scores exists between majors but no significant difference exists between treatment groups or in the interaction of treatment group and major. The subjects who did not follow instructions received the same information regardless of the treatment group. Since no selections were made and any hypothesis given was not based on information collected by the subject for the task, these subjects were not entered in the analysis of the dependent variables.

TABLE 22.--Major by Treatment Group Analysis of Variance of ACT Scores: Phase I-Elementary and Secondary Science Education Majors

Source	df	MS	F
Subjects who Received Instructions			
G(treatment group)	1	3.92	0.007[a]
M(major)	1	15557.98	28.917***
GM	1	10.20	0.019
Within cells	46	538.03	
Subjects who Followed Instructions			
G	1	359.36	0.857[b]
M	1	8097.47	19.307***
GM	1	232.81	0.555
Within cells	26	419.41	

*** Significant at the .001 level.

[a] Critical F at the .01 level = 4.08.
Critical F at the .05 level = 2.04.

[b] Critical F at the .01 level = 7.72.
Critical F at the .05 level = 4.23.

Selection of Tasks for Inclusion in Analysis

The first task in a series of experimental tasks has been shown to be a practice task (Laughlin, 1971) and the only task in the series affected by earlier information on the task (Olson, 1963). The performance measures on the first task did not correlate with either the second or third task in general as well as those measures on the last two tasks correlated with each other. These correlations are given in Table 23.

The two measures defining selection patterns were the percentage of positive instances and sequence of selections. Scheffe pair wise comparisons of the three tasks gave no significant differences with sequence of selections. The mean of the percentage of positive instances

TABLE 23.--Relationships of Performance Measures between Pairs of Tasks: Phase I-Elementary and Secondary Science Education Majors

Dependent Variables	First Task with Second Task	First Task with Third Task	Second Task with Third Task
Cor	.51***	.30	.48***
# S	.17	.12	.79***
Suf	.31	.19	.43**
I I	.55***	.38**	.72***
% +	.59***	.52***	.74***
Seq	.46***	.50***	.81***
MdT	.44***	.52***	.28
MnT	-.10	.13	.28

*** Significant at the .001 level. Critical value for r (N=51) = .44.

** Significant at the .01 level. Critical value for r (N=51) = .35.

in the first task was significantly different at the .05 level than the mean for the second or third task. The means for the second and third task were not significantly different at the .05 level. These results are reported in Table 24.

A two-way analysis of variance was computed on these measures with individuals and tasks as the two factors. The results of this analysis are given in Table 25 when computed with measures from all three tasks and when computed with measures on only the last two tasks. When the first task was disregarded the variation between the second and third tasks in the percentage of positive instances was not significant at the .25 level. The high consistency of subjects from the second to third task and the variation due to the first task led to the dropping of the measures on the first task from the data analysis.

TABLE 24.--Scheffe Comparisons of Mean Values for Percentage of Positive Instances and Sequence of Selections Between Tasks: Phase I Elementary and Secondary Science Education Majors

			Percentage of Positive Instances		
				Tasks	
			First Mean = 58.59	Second Mean = 71.92	Third Mean = 74.02
First	Mean S.D.	58.59 29.25		13.33*	15.43*
Second	Mean S.D.	71.92 22.81			2.10
Third	Mean S.D.	74.02 23.95			
			Sequence of Selections		
				Tasks	
			First Mean = 188.45	Second Mean = 188.00	Third Mean = 184.61
First	Mean S.D.	188.45 100.49		.45	3.84
Second	Mean S.D.	188.00 88.10			3.39
Third	Mean S.D.	184.61 87.45			

* Difference significant at the .05 level.

Distribution of Patterns

The measures of selection patterns for the subjects who did follow instructions were distributed in the third task as given in Table 26. Each measure was divided into three ranges of scores and the number of subjects using patterns in these ranges was recorded. The distributions of patterns fell in the four extreme cells, instance-centered analytic, instance-centered global, attribute-centered analytic

TABLE 25.--Individual by Task Analysis of Variance of Sequence of Selection and Percentage of Positive Instances: Phase I-Elementary and Secondary Science Education Majors

Source of Variance	df	Sequence of Selections Mean Sq.	Sequence of Selections F	Percentage of Positive Instances Mean Sq.	Percentage of Positive Instances F
All 3 Tasks					
Individuals	50	18345	5.12***	1424	5.41***
Tasks	2	225	15.92***	3573	13.59***
Residual	100	3581		263	
Second and Third Task					
Individuals	50	13979	9.79***	950	6.60***
Tasks	1	293	4.88[a]	112	1.28
Residual	50	1429		144	

*** Significant at the .001 level.

[a] Critical value at the .05 level for $F(1,50) = 4.04$.

TABLE 26.--Sequence of Selections by Percentage of Positive Instances Distribution of Patterns used by Subjects: Phase I-Elementary and Secondary Science Education Majors

			Percentage of Positive Instances 50% Global	67%	84%	100% Analytic
Sequence	100–167	Instance-Centered	11[a]	2	15	
	167–233	Mixed	1	0	4	
	233–300	Attribute-Centered	11	0	7	

[a] Frequency.

and attribute-centered global. Very few subjects made selections in a mixed sequence, scores from 167 to 233, or in the range of 67 to 84 percent of positive instances. Fifty percent of all instances were positive. As further indicative of consistency from task to task with respect to analytic and global patterns, the percentage of subjects who used these patterns from task to task are given in Table 27. Also given in Table 27 are the percentages of unsuccessful subjects who changed patterns on the following tasks. The results indicate a consistency

TABLE 27.--Percentage of Positive Instances Selected from Task to Task by Subjects: Phase I-Elementary and Secondary Science Education

	Tasks					
	First to Second		First to Third		Second to Third	
	All Subjects	Unsuccessful Subjects	All Subjects	Unsuccessful Subjects	All Subjects	Unsuccessful Subjects
A[a] to A	28%	9%	28%	9%	35%	17%
A to M	0	0	0	0	2	0
A to G	0	0	0	0	2	8
M to A	2	0	2	0	2	0
M to M	0	0	0	0	2	0
M to G	5	9	5	9	4	8
G to A	14	18	14	9	6	0
G to M	7	0	7	0	2	0
G to G	44	64	44	73	45	67

[a] A = Analytic; M = Mixed; and G = Global.

from task to task with some changes toward analytic patterns, particularly when global was the pattern used for the first task. The subjects who incorrectly identified the relevant attributes in general used a global pattern on all three tasks with little change in patterns following an unsuccessful solution to a task. The significance of these shifts in patterns was studied using a z test for the difference between two correlated proportions. The results are given in Table 28.

TABLE 28.--Significance of the Direction of the changes in Percentage of Positive Instances Selected from Task to Task by Subjects: Phase I Elementary and Secondary Science Education Majors

	First to Second	First to Third	Second to Third
		All Subjects	
Analytic to Not Analytic	z = -2.65**	-2.65**	-.82
Global to Not Global	z = +2.11*	+2.11*	+.38
		Unsuccessful Subjects	
Analytic to Not Analytic	z = -1.41	-1.00	-1.00
Global to Not Global	z = +.57	0.00	-1.41

** Significant at the .01 level.

* Significant at the .05 level.

Correlations of Variable Measures

The correlations for the independent variables which are measures of the individual characteristics and for the dependent variables which are performance measures for the second and third task are given in Table 29. ACT correlates significantly at the .01 level with the percentage of positive instances and the initial instance chosen as positive in the third task. This indicates that "more intelligent" individuals selected more first instances which were positive and used more positive instances, a more selective or analytic process, than "less intelligent" individuals. ACT relates to the major of the student with those students in secondary science teacher education having the higher ACT scores. More females select elementary education than secondary

TABLE 29.--Correlation Matrix for Individual Characteristics and Performance Measures for the Second and Third Tasks: Phase I-Elementary and Secondary Science Education Majors

	Sex	Maj	ACT[b]	Second Task Cor	# S	Suf	I I	% +	Seq	MdT	MnT	Third Task Cor	# S	Suf	I I	% +	Seq	MdT	MnT
Sex																			
Maj	-45*																		
ACT	-23	61*																	
Cor	-08	18	08																
# S	07	-05	-30	-28															
Suf	18	-11	-09	-08	14														
I I	01	06	19	33	-59*	17													
% +	-03	01	36	12	-79*	21	68*												
Seq	17	-08	12	-24	27	02	-05	-05											
MdT	-20	09	-01	25	-33	03	11	09	-30										
MnT	-09	09	-04	-06	13	16	-22	-17	11	44*									
Cor	16	33	11	48*	-14	-05	31	03	-22	15	06								
# S	12	-02	-40	-39*	79*	16	-51*	-69*	12	33	12	-19							
Suf	16	01	20	11	10	43*	13	03	06	08	10	08	22						
I I	-08	24	61*	28	-42*	21	72*	57*	-03	17	-08	28	-44*	35					
% +	-07	15	57*	38*	-62*	14	67*	74*	04	16	-09	32	-74*	27	72*				
Seq	04	00	00	-08	11	-03	07	07	81*	-18	12	-13	-02	-04	10	11			
MdT	04	-11	17	15	-13	11	18	14	-19	28	09	24	-15	11	22	16	-19		
MnT	04	-07	03	-14	15	16	-10	12	-14	21	28	21	18	21	01	-09	-25	68*	

[a] Correlations have been rounded to two digits and the decimal point omitted.

[b] N = 30 for ACT, N = 51 for all others.

* Significant at the .01 level. Critical value for r_{30} = .45; for r_{51} = .35.

education.

The measures of the dependent variables in the second task and the measures of the respective variables in the third task are related except for the two time measures. This indicates a consistency on the part of the subject from the second to third task. The time measures on the two tasks are not correlated significantly indicating some variation within individuals on time measures. The time measures also may have been affected by delays in information feedback to the subject. Although computer delays were not recorded in the times taken by the subject, a variation in computer delay time might alter the time for the subject to respond. However, the two measures mean request time and median selection time correlated significantly in each task. Initial instance selected (I I) correlates significantly at the .01 level with percentage of positive instances (% +) in both tasks. This gives evidence that those subjects who selected a high percentage of positive instances started their selections intentionally with a positive instance. These subjects also used a significantly fewer number of selections in each task than subjects who used a lower percentage of positive instances. This indicates that the analytic pattern of selections was more selective and more efficient. Those subjects who solved the second task correctly used fewer selections and a higher percentage of positive instances in the third task. This indicates that subjects who were successful on the second task learned to be more efficient and analytic on the third task. The means for the dependent variables in Phase I are given in Table 30.

TABLE 30 .--Means of Variables by Major, Treatment and Task for All Subjects who Followed Instructions
Phase I Elementary and Secondary Science Education Majors

Cell					ACT		Dependent Variables							
Major	Treatment	Task	N		N		Cor	# S	Suf	I I	% +	Seq	MdT	MnT
Elementary	Matrix	Second	9	Mean	4	39.25	.67	8.56	1.00	.44	68.22	211.89	5.33	11.44
				S.D.[a]		25.99[b]	.44	3.16	.14	.50	22.81	88.10	6.81	10.58
Elementary	Matrix	Third	9	Mean			.56	8.44	.89	.44	60.89	212.67	2.67	5.22
				S.D.[c]			.33	3.21	.30	.47	23.95	87.45	3.38	5.40
Elementary	Linear	Second	11	Mean	7	43.71	.64	8.09	1.00	.64	74.55	184.09	5.64	13.09
Elementary	Linear	Third	11	Mean			.91	6.91	.91	.64	76.82	161.45	6.91	11.00
Secondary	Matrix	Second	17	Mean	9	64.67	.65	8.00	.94	.53	70.24	169.24	4.59	11.24
Secondary	Matrix	Third	17	Mean			.94	8.06	.88	.65	71.41	171.59	3.71	8.06
Secondary	Linear	Second	14	Mean	10	85.60	1.00	8.00	1.00	.71	74.29	198.50	9.50	18.31
Secondary	Linear	Third	14	Mean			1.00	6.71	.93	.93	83.43	200.57	4.93	7.21

[a] S.D. = Standard Deviation across all four second tasks.

[b] Standard Deviation for ACT scores across all eight cells.

[c] S.D. = Standard Deviation across all four third tasks.

Effects of Major, Treatment and Task

A two-way analysis of variance of the dependent measures by major and treatment with repeated measures across tasks was computed with the BMD08V program. The means of the dependent measures used in the analysis are given in Table 31. The results of the analysis are given in Table 32.

The three-way interaction effect, major, treatment and task (MGT), on the correctness of the answer given by the subject was due to the decrease in correct answers in treatment group 1 of eleven education majors from the second to third task. All of the secondary science education majors in treatment group 2 answered both the second and third tasks correctly. The mean values for this measure, correct coded 1 and incorrect coded 0, are given in Table 33.

The two-way interaction effect, treatment and task (GT), on the number of selections made was due to the larger decrease from the second to third task in treatment group 2 compared to treatment group 1. The group which received the task information in a matrix form increased in efficiency more than those who received the task information in a linear form. The mean values of the number of selections by treatment group by task are given in Table 34.

The two-way interaction effect, major by task (MT), on the selection of initial instances was due to the secondary science education majors selecting more positive instances as initial instances in the third task than the second task. The elementary education majors selected slightly fewer positive initial instances on the third task than or the second task. The mean values for selection of initial

TABLE 31 .--Means of Variables by Major, Treatment and Task in Repeated Measures Sample of Phase I Elementary and Secondary Science Education Majors

Cell				Dependent Variables							
Major	Treatment	Task	N	Cor	# S	Suf	I I	% +	Seq	MdT	MnT
Elementary	Matrix	Second	9	.67	8.56	1.00	.44	68.22	211.89	5.33	11.44
Elementary	Matrix	Third	9	.56	8.44	.89	.44	60.89	212.67	2.67	5.22
Elementary	Linear	Second	9	.67	7.56	1.00	.67	78.22	180.56	5.56	10.11
Elementary	Linear	Third	9	.89	6.22	.89	.56	79.56	158.33	7.44	10.33
Secondary	Matrix	Second	9	.67	8.11	1.00	.56	73.00	155.78	4.33	10.56
Secondary	Matrix	Third	9	1.00	8.00	.89	.67	74.44	151.89	4.00	8.44
Secondary	Linear	Second	9	1.00	7.78	1.00	.78	75.89	187.44	7.44	14.33
Secondary	Linear	Third	9	1.00	6.11	.89	1.00	87.22	187.56	5.33	7.56

TABLE 32.--Major by Treatment by Task Analysis of Variance of Performance Measures with Repeated Measures across Tasks: Phase I-Elementary and Secondary Science Education Majors

Variable	Source	Error Term	df	MS	F
Cor	M (major)	Pw.MG[a]	1,32	.89	4.13[b]
	G (treatment)	Pw.MG	1,32	.50	2.33
	T (task)	PTw.MG	1,32	.22	3.20
	MG	Pw.MG	1,32	--	0.00
	MT	PTw.MG	1,32	.56	0.80
	GT	PTw.MG	1,32	.00	0.00
	MGT	PTw.MG	1,32	.50	7.20*
# S	M	Pw.MG	1,32	.68	0.04
	G	Pw.MG	1,32	33.35	2.07
	T	PTw.MG	1,32	11.68	5.67*
	MG	Pw.MG	1,32	1.12	0.07
	MT	PTw.MG	1,32	.12	0.06
	GT	PTw.MG	1,32	8.68	4.22*
	MGT	PTw.MG	1,32	.12	0.06
Suf	M	Pw.MG	1,32	.00	0.00
	G	Pw.MG	1,32	.00	0.00
	T	PTw.MG	1,32	.22	4.00
	MG	Pw.MG	1,32	.00	0.00
	MT	PTw.MG	1,32	.00	0.00
	GT	PTw.MG	1,32	.00	0.00
	MGT	PTw.MG	1,32	.00	0.00
I I	M	Pw.MG	1,32	.89	2.23
	G	Pw.MG	1,32	.89	2.23
	T	PTw.MG	1,32	.06	1.07
	MG	Pw.MG	1,32	.06	0.14
	MT	PTw.MG	1,32	.22	4.27*
	GT	PTw.MG	1,32	.00	0.00
	MGT	PTw.MG	1,32	.06	1.07

TABLE 32.--Continued.

Variable	Source	Error Term	df	MS	F
% +	M	Pw.MG	1,32	630	0.64
	G	Pw.MG	1,32	2211	2.26
	T	PTw.MG	1,32	52	0.37
	MG	Pw.MG	1,32	190	0.19
	MT	PTw.MG	1,32	397	2.85
	GT	PTw.MG	1,32	387	2.79
	MGT	PTw.MG	1,32	2	0.01
Seq	M	Pw.MG	1,32	7341	0.49
	G	Pw.MG	1,32	378	0.03
	T	PTw.MG	1,32	716	0.80
	MG	Pw.MG	1,32	26335	1.77
	MT	PTw.MG	1,32	351	0.39
	GT	PTw.MG	1,32	406	0.46
	MGT	PTw.MG	1,32	820	0.92
MdT	M	Pw.MG	1,32	.00	0.00
	G	Pw MG	1,32	100.30	4.04
	T	P .MG	1,32	11.70	1.03
	MG	w.MG	1,32	.30	.01
	MT	PTw.MG	1,32	3.10	.28
	GT	PTw.MG	1,32	8.70	.77
	MGT	PTw.MG	1,32	45.10	3.98
MnT	M	Pw.MG	1,32	16.00	0.31
	G	Pw.MG	1,32	50.00	0.98
	T	PTw.MG	1,32	249.40	11.57*
	MG	Pw.MG	1,32	.90	.002
	MT	PTw.MG	1,32	9.40	.44
	GT	PTw.MG	1,32	3.60	.16
	MGT	PTw.MG	1,32	138.90	6.44*

* Significant at the .05 level.

[a] Pw.MG = Person within major by Treatment.

[b] Critical F at the .05 level = 4.17.

TABLE 33.--Major by Treatment by Task Distribution of Mean Values of Correctness of Solutions: Phase I-Elementary and Secondary Science Education Majors

	Elementary Education Treatment Group		Secondary Science Education Treatment Group	
	1	2	1	2
Second task	.67	.67	.67	1.00
Third task	.56	.89	1.00	1.00

TABLE 34.--Task by Treatment Group Mean Values for Number of Selections: Phase I-Elementary and Secondary Science Education Majors

	Treatment Group	
	1	2
Second task	8.33	7.67
Third task	8.22	6.17

instances are given in Table 35.

TABLE 35.--Major by Task Distribution of Mean Values of Initial Instances Selected: Phase I-Elementary and Secondary Science Education Majors

	Major	
	Elementary Education	Secondary Education
Second task	.56	.67
Third task	.50	.83

The three-way interaction effect, major, treatment and task (MGT), on the mean request time was relatively complex. The mean time did decrease from the second to third task except for a slight increase in treatment group 2 of the elementary education majors. The large F value for the task effect would support the observation of a decrease in the mean request time from the second to third task. The mean values for the measure are given in Table 36.

TABLE 36.--Major by Task Distribution of Mean Values of Mean Request Time: Phase IElementary and Secondary Science Education Majors

	Elementary Education Treatment Group 1	2	Secondary Science Education Treatment Group 1	2
Second task	11.44	10.11	10.56	14.33
Third task	5.22	10.33	8.44	7.56

The correlation of .61 of ACT scores with major prompted a three-way multivariate analysis of covariance with ACT scores as the covariate. The mean values for the dependent variables of the sample used are given in Table 37. The results of this analysis are given in Table 38. The number of subjects with ACT scores was too small in some cells to compute the homogeneity of regression by the program used, MANOVA (Clyde, 1969). The covariance analysis removed all interaction effects, but the decrease in mean request time from the second to third task was still significant. The adjusted means of the dependent variables for this analysis are given in Table 39.

Phase II

Distribution of Subjects

The distribution of subjects who received the instructions in the program and those who followed instructions in Phase II of this st study is given in Table 40. A value of 1 was assigned to those subjects who followed instructions and a value of 0 to those who did not. This

TABLE 37.--Means of Variables by Major, Treatment and Task in Sample Used for Analysis of Covariance; Phase I Elementary and Secondary Science Education Majors

Cell Major	Treatment	Task	N		ACT	Cor	# S	Suf	I I	% +	Seq	MdT	MnT
Elementary	Matrix	Second	4	Mean	39.25	.75	8.75	1.00	.25	58.00	182.50	7.75	12.75
				S.D.[a]	25.99	.36	3.07	.29	.47	22.61	87.44	3.82	7.50
Elementary	Matrix	Third		Mean		.75	9.00	.75	.25	43.75	200.00	2.75	4.75
Elementary	Linear	Second	7	Mean	43.71	.57	8.71	1.00	.57	67.57	203.57	4.14	14.71
Elementary	Linear	Third		Mean		1.00	8.14	.86	.57	70.43	192.57	7.00	12.71
Secondary	Matrix	Second	9	Mean	64.67	.78	7.67	.89	.56	70.00	161.33	4.67	10.78
Secondary	Matrix	Third		Mean		1.00	7.44	.89	.67	76.33	160.22	3.78	8.00
Secondary	Linear	Second	10	Mean	83.60	.90	8.10	1.00	.60	74.60	175.60	6.20	12.30
Secondary	Linear	Third		Mean		.90	6.40	.90	1.00	84.30	178.30	5.00	7.60

[a] S.D. = Standard Deviation across all eight cells.

TABLE 38.--Major by Treatment by Task Analysis of Covariance of Performance Measures with ACT Scores Covariate: Phase I Elementary and Secondary Science Education Majors

Variable	Source	df	MS	F
Cor	M(major)	1,51	.16	1.22[a]
	G(treatment)	1,51	.01	.07
	T(task)	1,51	.42	3.24
	MG	1,51	.00	.01
	MT	1,51	.10	.76
	GT	1,51	.00	.00
	MGT	1,51	.35	2.72
# S	M	1,51	.85	.10
	G	1,51	1.10	.13
	T	1,51	8.07	.92
	MG	1,51	2.14	.24
	MT	1,51	1.84	.21
	GT	1,51	5.67	.65
	MGT	1,51	.36	.04
Suf	M	1,51	.01	.05
	G	1,51	.02	.30
	T	1,51	.15	1.80
	MG	1,51	.00	.00
	MT	1,51	.06	.70
	GT	1,51	.00	.03
	MGT	1,51	.04	.42
I I	M	1,51	.02	.11
	G	1,51	.28	1.35
	T	1,51	.92	1.98
	MG	1,51	.16	.76
	MT	1,51	.24	1.15
	GT	1,51	.13	.61
	MGT	1,51	.07	.33

TABLE 38.--Continued.

Variable	Source	df	MS	F
% +	M	1,51	2.41	.01
	G	1,51	278.78	.62
	T	1,51	228.15	.51
	MG	1,51	1021.49	2.27
	MT	1,51	458.18	1.02
	GT	1,51	243.01	.54
	MGT	1,51	156.30	.35
Seq	M	1,51	21251.00	2.81
	G	1,51	72.40	.01
	T	1,51	1.62	.00
	MG	1,51	8.44	.00
	MT	1,51	8.12	.00
	GT	1,51	203.90	.03
	MGT	1,51	864.30	.11
MdT	M	1,51	10.82	.74
	G	1,51	6.92	.47
	T	1,51	6.67	.45
	MG	1,51	1.90	.13
	MT	1,51	3.86	.26
	GT	1,51	23.56	1.60
	MGT	1,51	55.20	3.76
MnT	M	1,51	88.80	1.56
	G	1,51	34.69	.61
	T	1,51	232.06	4.08*
	MG	1,51	76.31	1.34
	MT	1,51	.54	.01
	GT	1,51	2.61	.05
	MGT	1,51	52.00	.91

* Significant at .05 level.

[a] Critical F at the .05 level = 4.04.

TABLE 39.--Means of Variables by Major, Treatment and Task Adjusted for Analysis of Covariance with ACT Scores as Covariate Phase I Elementary and Secondary Science Education Majors

Cell									Dependent	Variables			
Major	Treatment	Task	N		ACT	Cor	# S	Suf	I I	% +	Seq	MdT	MnT
Elementary	Matrix	Second	4	Mean	39.25	.74	7.66	1.02	.40	67.74	200.29	8.21	13.52
				S.D.[a]	25.99	.36	2.95	.29	.46	21.22	86.95	3.83	7.54
Elementary	Matrix	Third		Mean		.74	7.90	.78	.40	53.49	217.79	3.21	5.52
Elementary	Linear	Second	7	Mean	43.71	.56	7.83	1.02	.69	75.46	217.98	4.52	15.34
Elementary	Linear	Third		Mean		.99	7.26	.88	.69	78.32	206.98	7.38	13.34
Secondary	Matrix	Second	9	Mean	64.67	.78	7.76	.89	.54	69.18	159.84	4.63	10.71
Secondary	Matrix	Third		Mean		1.00	7.54	.89	.65	75.52	158.73	3.74	7.94
Secondary	Linear	Second	10	Mean	83.60	.91	9.08	.98	.47	65.92	159.74	5.79	11.61
Secondary	Linear	Third		Mean		.91	7.38	.88	.87	75.62	162.44	4.59	6.91

[a] S.D. = Standard Deviation across all eight cells.

TABLE 40.--Treatment Group Distribution of Subjects: Phase II Elementary Education Majors

	Treatment Groups							
	1	2	3	4	5	6	7	8
Subjects who Received Instructions	21	22	20	14	14	17	20	17
Subjects who Followed Instructions	11	10	11	10	5	9	13	12

categorization resulted in a point-biserial correlation (N=50) of .09, not significant at the .05 level, with ACT scores. The means of the ACT scores for each treatment group are given in Table 41 for those

TABLE 41.--Treatment Group Distribution of Mean Values of ACT Scores: Phase II-Elementary Education Majors

	Treatment Groups							
	1	2	3	4	5	6	7	8
All	52.82	34.43	42.83	58.58	41.00	51.93	42.64	46.30
Subjects	N=11	N=14	N=12	N=12	N=9	N=14	N=11	N=10
Subjects who followed	57.20	40.60	41.62	60.22	37.50	45.00	50.80	45.50
instructions	N=5	N=5	N=8	N=9	N=4	N=8	N=5	N=6

subjects for whom ACT scores were obtained. A one-way analysis of variance of ACT scores by treatment group was computed on each distribution with no significant effects as shown in Table 42.

Distribution of Patterns

The distribution of selection patterns made by subjects in Phase II of the study is shown in Table 43. As in Phase I, almost all patterns were classified in four categories with very few patterns

TABLE 42.--Treatment Group Analysis of Variance of ACT Scores: Phase II Elementary Education Majors

Source	df	MS	F
All Subjects			
Between Groups	7	377.32	0.60[a]
Within Groups	41	629.32	
Subjects who followed Instructions			
Between Groups	7	748.44	1.27
Within Groups	85	587.80	

[a] Critical value at .05 level for F (7, 41) = 2.25; for F (7, 85) = 2.15.

TABLE 43.--Sequence of Selections by Percentage of Positive Instances Distribution of Patterns Used by Subjects: Phase II-Elementary Education Majors

			Percentage of Positive Instances			
			50% Global	67%	84%	100% Analytic
Sequence	100–167	Instance-Centered	20	2	13	
	167–233	Mixed	0	0	3	
	233–300	Attribute-Centered	23	2	18	

with either a mixed sequence or with an intermediate percentage of positive instances. A further indication of consistency from task to task with respect to analytic and global patterns, the percentage of subjects who used these patterns from task to task are given for each possible change of pattern in Table 44. The significance of the changes as computed by the z test for the difference between two correlated

TABLE 44.--Percentage of Positive Instances Selected from Task to Task by Subjects: Phase II-Elementary Education Majors

	Tasks					
	First to Second		First to Third		Second to Third	
	All Subjects	Unsuccessful Subjects	All Subjects	Unsuccessful Subjects	All Subjects	Unsuccessful Subjects
A to A[a]	22%	22%	25%	20%	42%	18%
A to M	1	3	1	3	1	0
A to G	3	3	3	6	1	0
M to A	4	0	4	0	3	0
M to M	0	0	0	0	1	4
M to G	1	3	1	3	0	0
G to A	20	19	25	28	10	18
G to M	4	3	4	3	3	4
G to G	45	47	37	37	39	56

[a] A = Analytic; M = Mixed; G = Global.

TABLE 45.--Significance of the Direction of the changes in Percentage of Positive Instances Selected from Task to Task by Subjects: Phase II Elementary Education Majors

	First to Second	First to Third	Second to Third
		All Subjects	
Analytic to Not Analytic	z = -3.26**	-3.67**	-2.31*
Global to Not Global	z = +3.26**	+3.67**	+2.71
		Unsuccessful Subjects	
Analytic to Not Analytic	z = -1.41	-1.72	-2.00*
Global to Not Global	z = +1.67	+1.94	+2.24*

** Significant at the .01 level.

* Significant at the .05 level.

proportions are given in Table 45. The results indicate that those subjects who changed patterns changed toward more analytic patterns.

Correlation of Dependent Variable Measures

The correlations among the measures of the dependent variables were computed and are given in Table 46. The results were very similar to those in Phase I. The measures of all the dependent variables in the second task correlate significantly with the respective measures in the third task. A lower number of selections, higher percentage of positive instances selected significantly. The sufficiency of information obtained in the second task was related significantly to the number of selections and percentage of positive instances in the second task while the sufficiency of information in the third task was related significa significantly to percentage of positive instances. This indicates that those subjects who selected a higher percentage of positive instances were better able to identify sufficient information.

The measures of the mean request time and median selection timee were correlated with the time measures in the second and third task. The median selection time in the third task also was correlated significantly with the number of selections made in the second and third tasks.The lower the number of selections the longer was the time required to make each selection. The means of the dependent variables are given in Table 47.

Effects of Treatment and Tasks

The one-way analysis of variance of measures of dependent variables by treatment groups with repeated measures across tasks was computed using the BMDO8V program. The mean values of these measures for the subjects in the sample used for this analysis are given in

TABLE 46.--Correlation Matrix of Individual Characteristics and Performance Measures for the Second and Third Tasks: Phase II-Elementary Education Majors

			Second Task								Third Task							
	Sex	ACT[a]	Cor	# S	Suf	I I	% +	Seq	MdT	MnT	Cor	# S	Suf	I I	% +	Seq	MdT	MnT
Sex																		
ACT	-02[b]																	
Cor	-04	09																
# S	29	-22	-21															
Suf	12	07	25	41*														
I I	00	-02	30*	-39*	06													
% +	-04	15	27	-54*	32*	61*												
Seq	14	-18	-01	22	20	08	16											
MdT	10	-02	-03	-20	-20	12	25	-16										
MnT	08	12	01	-03	-14	08	-02	-10	71*									
Cor	-15	30	42*	-27	06	24	20	-04	04	24								
# S	23	-18	-19	68*	05	-37*	-52*	22	-22	-09	-35*							
Suf	22	07	03	26	44*	24	40*	23	19	02	04	02						
I I	01	05	20	-52*	-03	61*	52*	-05	15	06	26	-63*	-02					
% +	-10	14	21	-50*	14	52*	65*	00	12	-01	25	-85*	14	71*				
Seq	03	-25	-05	16	-06	-05	-14	74*	-21	-10	-10	18	-04	-12	-04			
MdT	-19	-01	-07	-33*	-41*	-04	00	-24	58*	51*	14	-33*	-16	07	01	-16		
MnT	00	-11	-16	-18	-34*	00	-09	-18	35*	41*	19	-12	-05	-06	-14	-14	65*	

[a] N = 50 for ACT; N = 81 for all others.

[b] Correlations have been rounded to two digits and the decimal point omitted.

* Significant at the .01 level. Critical value at .01 level for r_{50} =.35, for r_{81} =.28.

TABLE 47.--Means of Variables by Treatment and Task for All Subjects who Followed Instructions Phase II Elementary Education Majors

Treatment	Task	Instance Symbols	Sample	# of Relevant Attributes	N	Task	Cor	# S	Suf	I I	% +	Seq	MdT	MnT
							Dependent Variables							
1	Linear	Letters	Matrix	Given	11	2	.82	9.18	1.00	.55	70.45	217.3	6.00	14.91
						3	.82	9.00	.91	.45	70.27	223.1	2.82	6.18
2	Linear	Numbers	Matrix	Given	10	2	.70	9.50	1.00	.50	63.20	117.3	3.50	7.20
						3	.60	8.50	1.00	.50	67.80	111.70	2.60	4.60
3	Linear	Letters	Linear	Given	11	2	.64	8.91	.82	.55	65.64	197.7	5.64	11.00
						3	.55	8.64	1.00	.55	67.73	218.2	4.55	7.64
4	Linear	Letters	Matrix	Not Given	10	2	.90	7.60	.90	.70	77.70	255.6	4.50	9.00
						3	.90	7.60	1.00	.60	84.30	261.3	2.70	8.00
5	Linear	Numbers	Matrix	Not Given	5	2	.40	8.60	1.00	.60	78.60	232.0	5.20	9.40
						3	.80	8.20	1.00	.60	75.40	144.0	4.80	15.20
6	Linear	Letters	Linear	Not Given	9	2	.56	9.78	1.00	.67	67.33	247.0	3.11	10.56
						3	.78	8.56	1.00	.67	75.67	261.9	2.22	5.89
7	Matrix	Letters	Matrix	Given	13	2	.77	8.23	1.00	.62	78.88	204.6	4.77	10.85
						3	.85	6.00	1.00	.77	93.38	207.7	3.92	8.08
8	Matrix	Letters	Matrix	Not Given	12	2	.83	6.83	.75	.67	65.25	217.2	2.83	6.83
						3	.75	7.50	.83	.75	79.33	233.6	3.00	6.08
					S.D.[a]	2	.45	3.49	.26	.49	26.76	91.94	4.20	7.45
					S.D.[b]	3	.43	3.11	.19	.49	25.03	91.10	2.58	7.59

[a] S.D. = Standard Deviation across all eight treatments for Task 2.
[b] S.D. = Standard Deviation across all eight treatments for Task 3.

Table 48. The results of the analysis are given in Table 49. The only effect significant at the .05 level was the same effect as in Phase I, a decreased median selection time from the second to third task.

In Phase I, the analysis of main effects used major as a blocking variable. In Phase II, all subjects were elementary education majors. Thus, a one-way analysis of covariance was computed with the MANOVA program using ACT scores as a covariate. The mean values for the dependent variables for the subjects with recorded ACT scores are given in Table 50. The results of this analysis are reported in Table 51. In this analysis, the mean request time (MnT) decreases from the second task to the third task. Adjusted cell means for mean request time are 8.56 seconds for the second task and 6.32 seconds for the third task.

The median selection time (MdT) and sequence of selection (Seq) differed significantly with treatment groups. The estimates of the means adjusted for the covariate, ACT scores, are given in Table 52. The Scheffe method of multiple comparisons was used to investigate the effects of the changes in task characteristics. Four contrasts were considered, one for each of the task characteristics. These contrasts are given in Table 53.

The only contrast between task characteristics which gave a significant effect was the matrix presentation contrasted with the linear presentation of information feedback during the task. The subjects given the matrix presentation chose positive initial instances more often than those given the linear presentation. This might indicate that a more compact ordered display of information leads to a more analytic process.

TABLE 48.--Means of Variables by Treatment and Task in Repeated Measures Sample of Phase II Elementary Education Majors

Treatment							Dependent Variables							
	Task	Instance Symbols	Sample	# of Relevant Attributes	N	Task	Cor	# S	Suf	I I	% +	Seq	MdT	MnT
1	Linear	Letters	Matrix	Given	5	2	.8	9.2	1.0	.4	71.4	215.6	6.2	13.6
						3	.8	9.4	.8	.6	68.4	211.8	2.8	7.2
2	Linear	Numbers	Matrix	Given	5	2	.6	11.0	1.0	.4	56.8	125.6	4.0	7.2
						3	.4	9.4	1.0	.4	67.4	114.4	2.6	4.2
3	Linear	Letters	Linear	Given	5	2	.6	6.4	.6	.8	74.6	190.0	8.6	14.2
						3	.6	7.6	1.0	.8	66.2	200.0	7.0	12.0
4	Linear	Letters	Matrix	Not Given	5	2	1.0	6.8	1.0	.8	89.2	263.2	4.2	5.8
						3	.8	6.8	1.0	.8	89.2	290.0	2.4	4.4
5	Linear	Numbers	Matrix	Not Given	5	2	.4	8.6	1.0	.6	78.6	232.0	5.2	9.4
						3	.8	8.2	1.0	.6	75.4	144.0	4.8	15.2
6	Linear	Letters	Linear	Not Given	5	2	.8	8.4	1.0	.8	79.4	260.0	3.2	10.8
						3	1.0	7.2	1.0	.8	89.2	260.0	2.4	4.6
7	Matrix	Letters	Matrix	Given	5	2	.8	9.0	1.0	.4	72.6	206.6	4.2	10.8
						3	.8	6.4	1.0	.8	84.4	220.0	3.6	12.6
8	Matrix	Letters	Matrix	Not Given	5	2	.8	6.8	.8	.6	59.6	229.4	1.8	6.6
						3	1.0	7.8	.8	.6	79.4	280.8	2.2	5.2

TABLE 49.--Treatment by Task Analysis of Variance of Performance Measures with Repeated Measures across Tasks: Phase II Elementary Education Majors

Variables	Source	Error Term	df	MS	F
Cor	G(treatment)	Pw.G[a]	7,32	.26	.89
	T(task)	PTw.G	1,32	.05	.50
	GT	PTw.G	7,32	.11	1.07
# S	G	Pw.G	7,32	13.88	.72
	T	PTw.G	1,32	3.61	.92
	GT	PTw.G	7,32	4.27	1.08
Suf	G	Pw.G	7,32	.08	1.03
	T	PTw.G	1,32	.01	.40
	GT	PTw.G	7,32	.07	2.23
I I	G	Pw.G	7,32	.23	1.59
	T	PTw.G	1,32	.11	.11
	GT	PTw.G	7,32	.06	.39
% +	G	Pw.G	7,32	783.00	.67
	T	PTw.G	1,32	437.00	1.41
	GT	PTw.G	7,32	234.00	.76
Seq	G	Pw.G	7,32	25122.50	2.11
	T	PTw.G	1,32	.61	.00
	GT	PTw.G	7,32	4115.50	2.22
MdT	G	Pw.G	7,32	31.54	1.08
	T	PTw.G	1,32	28.80	4.79*
	GT	PTw.G	7,32	3.26	.54
MnT	G	Pw.G	7,32	106.20	.85
	T	PTw.G	1,32	52.80	1.55
	GT	PTw.G	7,32	40.30	1.18

[a] Pw.G = Person within Treatment Group.

* Significant at the .05 level. Critical values for $F_{7,32} = 2.32$; $F_{1,32} = 4.15$.

TABLE 50.--Means of Variables by Treatment and Task in Sample Used for Analysis of Covariance Phase II Elementary Education Majors

Treatment	Task	Instance Symbols	Sample	# of Relevant Attributes	N	Task	ACT	Cor	# S	Suf	I I	% +	Seq	MdT	MnT
							Dependent Variables								
1	Linear	Letters	Matrix	Given	5	2	57.2	.60	9.60	1.0	.40	63.20	220.4	1.80	10.40
						3		.80	9.80	.8	.20	60.20	212.2	2.40	5.00
2	Linear	Numbers	Matrix	Given	5	2	40.6	.60	9.80	1.0	.40	59.00	121.2	4.20	5.60
						3		.40	8.00	1.0	.40	67.40	115.0	2.80	4.20
3	Linear	Letters	Linear	Given	8	2	41.6	.75	10.12	1.0	.50	64.25	203.1	3.25	7.75
						3		.50	8.88	1.0	.50	70.38	225.0	2.88	4.50
4	Linear	Letters	Matrix	Not Given	9	2	60.2	.89	7.11	.9	.78	80.78	256.2	4.56	9.22
						3		.89	7.11	1.0	.67	88.11	257.0	2.89	8.22
5	Linear	Numbers	Matrix	Not Given	4	2	37.5	.25	9.25	1.0	.50	73.50	215.0	5.25	8.75
						3		.75	7.25	1.0	.50	81.75	150.0	4.75	15.50
6	Linear	Letters	Linear	Not Given	8	2	45.0	.50	10.25	1.0	.62	63.38	240.4	2.75	10.25
						3		.75	8.88	1.0	.62	72.75	257.1	2.12	5.62
7	Matrix	Letters	Matrix	Given	5	2	50.8	.80	8.00	1.0	.40	80.00	202.6	4.20	10.80
						3		.80	5.60	1.0	.80	99.00	180.0	4.40	5.60
8	Matrix	Letters	Matrix	Not Given	6	2	45.5	.83	8.00	1.0	.83	80.83	270.0	2.33	5.33
						3		.83	7.67	1.0	.83	82.67	237.3	1.67	4.17
						S.D.[a]	24.6	.46	3.19	.14	.50	24.41	83.6	1.92	5.58

[a] S.D. = Standard Deviation across all cells.

TABLE 51.--Treatment by Task Analysis of Covariance of Performance Measures with ACT Scores as Covariate: Phase II Elementary Education Majors

Variable	Source	Error Term	df	MS	F
Cor	G(treatment)	Subj w. GT	7,83	.20	.94
	T(task)	Subj w. GT	1,83	.04	.19
	GT	Subj w. GT	7,83	.17	.78
# S	G	Subj w. GT	7,83	14.92	1.49
	T	Subj w. GT	1,83	26.01	2.60
	GT	Subj w. GT	7,83	2.68	.27
Suf	G	Subj w. GT	7,83	.02	1.04
	T	Subj w. GT	1,83	.00	0.00
	GT	Subj w. GT	7,83	.02	1.12
I I	G	Subj w. GT	7,83	.35	1.35
	T	Subj w. GT	1,83	.00	.00
	GT	Subj w. GT	7,83	.08	.31
% +	G	Subj w. GT	7,83	1217.16	2.09
	T	Subj w. GT	1,83	1267.35	2.13
	GT	Subj w. GT	7,83	103.40	1.17
Seq	G	Subj w. GT	7,83	30076.51	4.85*
	T	Subj w. GT	1,83	1056.19	.17
	GT	Subj w. GT	7,83	2167.88	.35
MdT	G	Subj w. GT	7,83	11.81	3.17*
	T	Subj w. GT	1,83	10.24	2.74
	GT	Subj w. GT	7,83	1.73	.46
MnT	G	Subj w. GT	7,83	56.57	1.80
	T	Subj w. GT	1,83	125.44	3.99*
	GT	Subj w. GT	7,83	35.35	1.12

* Significant at the .05 level.

TABLE 52.--Means of Variables by Treatment and Task Adjusted for Analysis of Covariance with ACT Scores as Covariate Phase II Elementary Education Majors

Treatment	Task	Instance Symbols	Sample	# of Relevant Attributes	N	Task	ACT	Cor	# S	Suf	I I	% +	Seq	MdT	MnT
								Dependent Variables							
1	Linear	Letters	Matrix	Given	5	2	57.2	.58	9.80	1.0	.40	62.21	231.1	1.81	10.45
						3		.78	10.00	.8	.20	59.21	222.9	2.41	5.05
2	Linear	Numbers	Matrix	Given	5	2	40.6	.62	9.64	1.0	.40	59.80	112.6	4.19	5.56
						3		.42	7.84	1.0	.40	68.20	106.4	2.79	4.16
3	Linear	Letters	Linear	Given	8	2	41.6	.77	9.99	1.0	.50	64.94	195.7	3.24	7.72
						3		.52	8.74	1.0	.50	71.06	217.6	2.87	4.47
4	Linear	Letters	Matrix	Not Given	9	2	60.2	.86	7.38	.9	.78	79.47	270.4	4.56	9.28
						3		.86	7.38	1.0	.67	86.80	271.2	2.90	8.28
5	Linear	Numbers	Matrix	Not Given	4	2	37.5	.28	9.02	1.0	.50	74.63	202.8	5.24	8.70
						3		.78	7.02	1.0	.50	82.88	137.8	4.74	15.45
6	Linear	Letters	Linear	Not Given	8	2	45.0	.51	10.18	1.0	.62	63.70	236.9	2.75	10.23
						3		.76	8.81	1.0	.62	73.07	253.6	2.12	5.61
7	Matrix	Letters	Matrix	Given	5	2	50.8	.79	8.06	1.0	.40	79.70	205.8	4.20	10.82
						3		.79	5.66	1.0	.80	98.70	183.2	4.40	5.62
8	Matrix	Letters	Matrix	Not Given	6	2	45.5	.84	7.94	1.0	.83	81.10	267.1	2.33	5.32
						3		.84	7.61	1.0	.83	82.94	234.4	1.66	4.15
						S.D.[a]	24.6	.46	3.17	.14	.51	24.41	78.7	1.93	5.61

[a] S.D. = Standard Deviation across all cells.

TABLE 53.--Task Characteristics by Treatment Group Constants for Scheffe Contrasts: Phase II-Elementary Education Majors

	Treatment Groups							
	1	2	3	4	5	6	7	8
Number of Relevant Attributes Given	+1[a]	+1	+1	-1	-1	-1	+1	-1
Matrix in Sample	+1	+1	-3	+1	+1	-3	+1	+1
Letters used for Instances	+1	-3	+1	+1	-3	+1	+1	+1
Matrix presentation in Experimental Task	-1	-1	-1	-1	-1	-1	+3	+3

[a] + indicates task characteristics present.
- indicates task characteristics not present.

Pair wise Scheffe comparisons were computed on those variables which yielded a significant treatment effect across all eight treatment groups. The comparison of the largest mean, 4.99 seconds, with the smallest mean, 2.00 seconds, for the median selection times showed no significant difference at the .05 level. The pair wise comparison of the largest mean 270.77, with the smallest mean, 109.49, for the sequence of selections showed a significant difference at the .001 level. The largest mean was the treatment in which the subject received instructions in a matrix, was told the number of relevant attributes, task feedback information in a linear form and instances denoted by numbers. The treatment in which the smallest mean for the sequence of selections occurred differed in that the number of relevant attributes was not given and instances were denoted by letters. The second smallest mean was the other treatment in which instances were denoted by letters.

A sequence of selections with a low score indicated an instance-centered sequence. These results indicated that subjects may prefer to make selections in which the dimensions denoted by numbers is held constant while the dimensions denoted by letters is altered.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This study identified patterns in selections made by subjects during tasks in attaining a concept. The tasks were administered and performance measures were collected at on-line computer terminals. These measures included the correctness of the solution given by the subject, number of selections, nature of initial instances selected, percentage of positive instances, sufficiency of information obtained by the subject prior to giving hypothesis, the sequence of selections, median selection time and mean request time for each task.

The study was conducted in two phases. In Phase I, elementary teacher education and secondary science teacher education majors were given the tasks in two treatments, matrix or linear presentation of information feedback to the selections made. The major emphasis of Phase I was the identification of patterns and the relationship of these patterns to individual characteristics. In Phase II, only elementary teacher education students were given the tasks in eight treatments by varying four task characteristics. The four task characteristics were: 1) matrix or linear presentation of sample task; 2) number of relevant attributes given or not given; 3) symbols used for instances were letters or numbers; and 4) matrix or linear present presentation of information feedback to subject's selections during the task. The major emphasis of Phase II was a study of the effects of varying the task characteristics.

Eighty-six percent of the secondary science teacher education and fifty-six percent of the elementary teacher education majors, followed instructions correctly. The subjects who did not follow instructions correctly were not included in the analysis of results due to insufficient data. Correlations among the ability to following ins instructions, major and ACT scores of the subjects was significant at the .01 level for Phase I. This finding provides support to the finding of Osler and others (1962) that intelligence measures are rela related to the following of instructions. In Phase II with only elementary education majors, no significant correlation was found between following instructions and ACT scores. This indicates that the ability to follow instructions may be related to the major field of interest or prior experience of the subject as much or more than the general intelligence of the subject.

The patterns of selections made by the subject were identified in terms of the sequence of selections made and the percentage of posi positive instances selected. The sequence of selections was a measure of the consistency with which the subject varied the selection of attr attributes or instances. If a subject selected the different attributes within one instance, this sequence was classified as instance-centered. If a subject selected one attribute across different instances, this s sequence was classified as attribute-centered. The varying percentages of positive instances selected were categorized as analytic or global patterns. Subjects using an analytic pattern selected only positive instances. In Phase II with only elementary education majors, no significant correlation was found between following instructions and ACT scores. This indicates that the ability to follow instructions in a science-related task may be more related to the major field of interest of the subject than to the general intelligence of the subject.

The sex of the subjects was not correlated significantly with any of the measures except that of major. Females were more likely to be elementary education majors.

The patterns of selections made by the subject were identified in terms of the order of selections made in attributes and instances and the percentage of positive instances. Subjects used attribute-centered or instance-centered sequences consistently from task to task. Subjects also used analytic or global patterns consistently.

The measure of the sequence of selections indicated a dichotomous measure since most subjects either varied instances or varied attributes consistently but not both. Most subjects either used an anlaytic or global pattern of selections in choosing only positive instances or positive and negative instances equally.

The subject who used an analytic pattern began the obtaining of information from a positive instance indicating a pre-selection intent to select positive instances. These subjects also used significantly fewer instances to reach the solution to the task and reached the correct solution more often than subjects who used a global pattern. The subjects who used an analytic pattern also tended to require more time to make selections indicating a more thoughtful approach to making selections. The tendency while proceeding from task to task was for most subjects to maintain the patterns used but if any changes were made in patterns they were toward analytic patterns.

The effect of changes in task characteristics was very limited. No effect was caused by matrix or linear presentations of the sample task instructions. This supports the general finding that instructions have little if any effect on performance measures.

The effect of presenting more information by giving the number of relevant attributes was not significant although some evidence indicated this made the task easier and a lower number of selections were required to find the solution.

The effect of changing the symbols used for instances and attributes did seem to make a difference in the sequence of selections. Subjects tended to vary alphabetic symbols more frequently than varying numberic symbols.

The presentation of the feedback in a matrix form to the subject following selections did tend to make the task easier in that the subjects solved the task correctly more often with the matrix organization than the linear presentation.

The effects of presenting a series of tasks was significant in that the first task was handled differently than the latter tasks by the subjects. The first task acted as a practice task after which the subject "settled down" to the task. The time required to make requests and decisions did decrease across tasks.

Recommendations for Further Study

Task Characteristics

The series of three tasks could be extended to several more tasks. This would permit changes in the tasks presented to each individual after several tasks have been presented to study effects within individuals. The extension of the series of tasks could be made over a lengthy period of time to study changes in performance over time. This would be particularly significant with the study of younger children in the developmental years.

The large number of subjects who did not follow instructions did not contribute data as to their selection patterns. It might be hypothesized that these subjects were in some way different than those subjects who followed instructions. To obtain more information, more practice tasks and more explicit feedback to errors might be provided until all or almost all subjects made valid selections before proceeding to the experimental tasks.

The use of tasks which are more realistic in that actual materials or substances are simulated would be useful in extending the conclusions to an instructional setting.

Individual Characteristics

The background of the subjects taking tasks as used in this study might me more fully examined. Particular emphasis should be placed on obtaining cognitive style or personality measures on the subjects. Some measure of the familiarity of the subject with the experimental task should be incorporated in a study of tasks which relate to prior experience. The age of the subject might have a significant effect on the patterns which a subject would use. The administration of tasks of concept-attainment to subjects of widely varied ages would provide information on this effect. The use of an on-line computer terminal would be very useful in reproducing the same treatments in a wide variety of situations and permitting random selection of programmed task characteristics and assignment to treatments randomly.

Performance Measures

The performance measures used in this study might be modified to provide more information. The selection and request times might be extended to include reading time of instructions for each subject and some information on computer delays in feedback. The sufficiency of information obtained might be extended to provide information on the amount of redundant information obtained. This would be selections made following the obtaining of sufficient information to find the correct solutions. This sufficient information could be separated into the information required to exclude irrelevant attributes, those not matching on positive instances, or to include relevant attributes, those matching on positive instances. These measures might be taken as a measure of the efficiency of a subject's patterns.

Implications

The lack of effects due to instructions should lead to a careful consideration of the amount and type of materials written as instructions for problems or tasks in concept-attainment. This should be evident especially with respect to computer-administered instructions which may be costly in time and finances. More effort should be made in providing practice on tasks than written instructions on how to do the task.

The tendency for the matrix form of feedback following the subject's selections suggests a need to develop compact and organized presentation of information.

The evidence of consistent patterns for subjects in selecting information suggests that the amount of information available to a subject in attaining concepts should be varied. The subject who uses an analytic pattern might not require many examples to attain a concept while a subject who uses a global pattern might require a larger field of observation from which to attain concepts.

APPENDIX

COMPUTER ASSISTED INSTRUCTION
STUDENT USE SHEET
(fn rmp)

____________ University Course	____________ Instructor	____________ Student's Name
____________ Student Number	____________ CAI Course Name	____________ 4-Digit ID Number

INSTRUCTIONS FOR CAI SYSTEM USE

1. Turn on the typewriter terminal!

2. Be sure the switch on the lower left of the table is on COM.

3. Using the DATA phone:

   a. Press the TALK button.
   b. Dial 2-3600.
   c. When you hear a high-pitched tone, press the DATA button.
   d. Replace the receiver.

4. Using the typewriter terminal:

   ****
   * WARNING: Use the Numbers on the top row of the *
   * Keyboard for Numbers. Do NOT use the capital *
   * letter O for zero; nor, the lower-case l (L) *
   * for the number (one) 1. *
   ****

   a. FIRST: type: ____________ (then, press the 'RETURN' key).

   b. SECOND: type the terminal ID (located below the space bar); then, press the 'RETURN' key. If no terminal ID is available, type the name of the building, where you are located, and, then, press the 'RETURN' key.
   EXAMPLE: ZM01

   c. THIRD: when asked for your 4-digit ID number, type ________, then, press the 'RETURN' key.

5. When you finish your CAI session, turn OFF the typewriter terminal and the slide projector (if used).

6. Report difficulties to the local CAI aide or call 2-9821. (Use a phone other than your DATA phone, if possible.)

7. If the typewriter stops for a minute or two, while you are working; then, the system may have failed. Call 2-9821 to verify a system failure. To resume working, you must redial (2-3600) to establish communication with the computer.

****
* BRING THIS SHEET WITH YOU EACH TIME *
* YOU RETURN TO THE TERMINAL, PLEASE! *
****

ANALYTICAL TECHNIQUE

COMPUTER SIMULATION

This activity presents a computer simulation of an analysis type problem. It is intended to provide practice in solving problems involving the identification of differences in the properties of materials.

The following items should be noted carefully:

1. Computer terminals for CAI are available in several locations across campus. Sign up sheets for terminal use also are available.

196A Arps Hall	215 Main Library
112 Dental Building	353 Lincoln Tower
108A Cunz Hall	West Campus Learning Resources Center

2. If at any time you have difficulty, contact the CAI aide at the terminal location or Tom Smith in 252 Arps Hall.

3. It is recommended that you use terminals between 8:00 a.m. and 5:00 p.m. on weekdays because CAI aides are on duty at these times only.

4. If you have not used a computer terminal previously, it is recommended that you sign on a demonstration program by typing s2/demo and spend some time with this program.

5. After looking at "demo" or if you have used a computer terminal previously, follow the instructions on the attached sheet carefully for "cmatid."

6. The program requires approximately thirty minutes but may take slightly longer. You should attempt to finish the program at one sitting.

7. In order to complete the assignment, the paper from the entire program printout should be turned in to either 336 Ramseyer or Tom Smith in 252 Arps by April 21.

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