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Examination of the learning situation might suggest that if students are exposed to situations focusing on inquiry and student involvement, certain changes should occur in student cognitive and affective behaviors as a result of interacting with the strategies of inquiry of a curriculum. From the curriculum materials of "Science - A Process Approach" four strategies of inquiry in science were selected for evaluation: classifying, observing, using number relations, and recognizing and using space/time relations. A sample of 95 fourth, fifth, and sixth grade students received five months of instruction in the strategies of inquiry. Analysis indicated that the most efficient strategy of inquiry for bringing about behavioral change was that of using numbers, followed by "classifying," "space/time relations," and "observing." There appeared to be no consistent pattern among grades and no sex differences in the relationship of the strategies of inquiry to behavior change. Apparently no single strategy of inquiry in science can be used to predict behavioral change in all of the behavioral criteria. (BC)

THE RELATIONSHIP BETWEEN THE STRATEGIES OF INQUIRY IN SCIENCE AND STUDENT COGNITIVE AND AFFECTIVE BEHAVIORAL CHANGE

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THE PROBLEM

Current curriculum organizations in science teaching for the elementary school place emphasis on inquiry or problem-solving. For such curriculum organizations to provide experience opportunities in inquiry situations it may be assumed that the student is actively involved in meaningful activity. Bruner (1960) suggests that performance by the student is necessary in order to know what he has understood. Piaget (1964) presents the concept that learning is provoked by situations and must involve active assimilation.

Active assimilation through experience and discovery (i.e. through student involvement) implies a change in observed behavior. Ripple (1964) suggests that from changes in observed behavior one might then infer changes in cognitive and affective behaviors.

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These behaviors may be described as internalized mental activities, influenced by learning experiences and revealed through observable behavior. Bloom (1956) suggests that these behaviors may be revealed in one or more of the factors associated with intellectual abilities and skills.

Although cognitive behavior is more clearly identified as a faculty of knowing as distinguished from the influence of feeling, there is considerable research indicating that cognitive and affective behavior cannot be completely separated (Bloom and Broder, 1950; Johnson, 1955; Russell, 1956; Wertheimer, 1945).

Bruner (1960) has emphasized the importance of strategies with which an individual approaches a task or solves a problem.

Gagné (1963) suggests:

> It seems reasonable to consider that strategies are mediating principles which do not appear in the performance of the task itself, but which may never-the-less affect the speed or excellence of that performance.... It is also possible to conceive of them as having principle like qualities, and of being made up essentially of a chain of concepts.... (Gagné, 1963, p. 45).

Discussing the design of instruction Gagné (1963) continues:

> There is considerable interest in the learning of strategies in connection with education in science, since scientific methods may themselves be viewed as containing strategies. Science educators frequently emphasize the importance of learning of "processes" (Such as observation, classification, inference, model building) to instruction in the sciences. (Gagné, 1963, p. 46).

It is thus assumed that "processes" and strategies of science are related and therefore a curriculum organization in science teaching that emphasizes inquiry might be considered to be concerned with strategies of inquiry. Furthermore, one might hypothesize that exposure to situations focusing on inquiry and student involvement should evoke changes in student cognitive and affective behaviors as a consequence of interacting with the strategies of inquiry of a curriculum. Figure 1 represents a conceptual model of such hypothesized interactions.

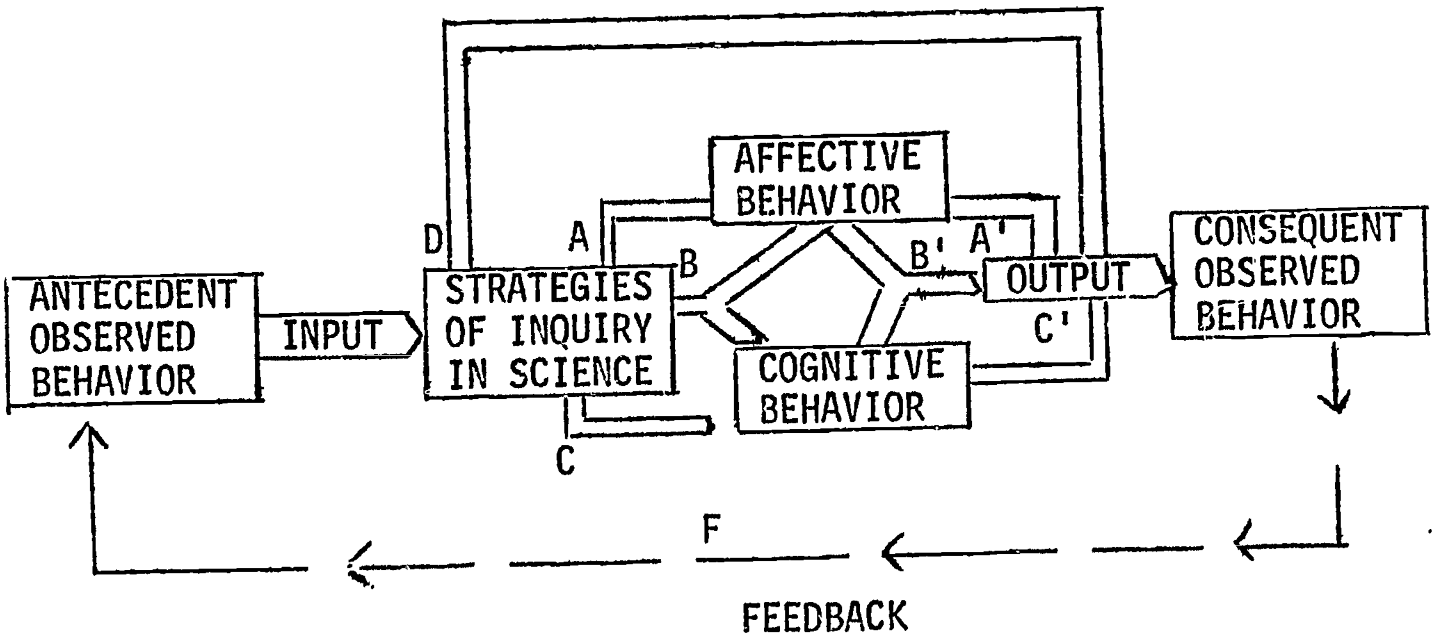
As identified in the curriculum materials of Science-A Process Approach, these four strategies of inquiry in science were selected for study: (1) classifying, (2) observing, (3) using number relations, and (4) recognizing and using space/time relations.

With these strategies of inquiry, what specific behaviors could be expected to be altered? Would, for example, the strategies of inquiry in science alter a student's problem-solving ability? Gagné and Brown (1961) suggest that the best learning performance results from guided discovery and that in problem-solving performance it appears "what is learned" is less important than "how it is learned". Is it possible that the approach to learning may be a significant factor in problem-solving ability?

McNemar (1955) finds fluency, past experience, and variability

FIGURE 1

MODEL OF INTERACTION OF STRATEGIES
AND
AFFECTIVE AND COGNITIVE BEHAVIOR



WHERE: A = Strategies of inquiry in science entering affective areas.

B = Strategies of inquiry in science with effects on affective and cognitive areas.

C = Strategies of inquiry in science entering cognitive areas.

D = Strategies of inquiry in science with no effect on affective or cognitive areas.

F = Feedback effects which might influence interaction in subsequent school years or in another curriculum organization.

A'= Alteration of affective behavior.

B'= Alteration of affective and cognitive behavior.

C'= Alteration of cognitive behavior.

as factors in problem-solving ability, while Gagné and Smith (1962) add the factor of verbalization.

Bloom (1964), in disucssing the emphasis of most intelligence tests on logical reasoning and problem solving, points to the factor of an environment that restricts opportunities to solve problems or think clearly, that discourages the individual and is likely to retard intelligence development. Several studies (Rogers, 1930; Louise, 1947; Tozer and Larwood, 1958) suggests that new and intensive learning experiences have a greater effect on developing problem-solving ability than continuation of the same experiences.

Bloom (1964) makes it clear that the stability of measured intelligence increases with age. A number of studies on cognition suggest that cognitive behavioral changes occur more easily as age increases (Bousfield, Easterson, and Whitmark, 195[illegible]; Bruner, 1964) and that age is a more significant factor than IQ in the ability to learn simple associations (Akutagawa and Benoit, 1959). For Burt (1958) intelligence seems to become more and more differentiated with age. Can a curriculum sequence utilizing strategies of inquiry provide the learning-experience opportunities, the environment, and the need to solve problems? If it does so, can such a sequence result in more variation and change in the quantity and quality of tested intelligence?

Butts (1962), in a study of children's concept development as related to experience, found performance more closely related to past experience than to IQ. This suggests that performance in a specific behavior may be related to a set of factors other than IQ. One such factor research by McBee and Duke (1960) was the interrelationships of intelligence and motivation on academic achievement. Motivation appeared to be a significant factor in academic achievement in the areas of reading, arithmetic, and science. McBee and Duke inferred that increasing motivation results in about the same increment in achievement regardless of intelligence. Available evidence seems to suggest that achievement is highly dependent on the factors of interest, motivation and intelligence.

Studies of the relationship of attitude toward a subject area and knowledge gained suggest the importance of student interest in developing a positive attitude toward a subject area. Weller (1933) concluded that attitudes and skills could be developed with conscious effort, but that they couldn't be expected to develop as concomitants of teaching facts alone. Greenberg (1964) found that attitude change is consistently related to information gain and is accompanied by a parallel amount of cognitive change. Perrodin (1966) found that students attitude toward elementary school science was favorable from grades four to six but began to decline at grade eight. Work by Gardner and Lambert (1959) indicates that there can be a powerful link between school attainment in a subject and the attitude of a learner. Evidence seems to suggest that the opportunity to be an active participant in learning activities rather than a passive recipient, to be involved in experience opportunities in which the teacher guides rather than tells, and to be able to express oneself freely are all factors leading to increased student interest. If these are factors leading to student interest, might not performance in the strategies of inquiry in science lead to more positive attitudes toward science?

Gibson (1963) describes another dimension of behavior -- that of attending, which may be related to selectivity in perception. Available evidence of the effect of task performance on attending behavior is not clear. Is it possible that attending ability among other behavioral factors, may be influenced by the strategies of inquiry in science?

Verbal fluency, ideational fluency, and perceptual closure may be factors of cognitive behavior which, according to Guilford, Fruchter, and Kelly (1959) may be closely associated with another dimension, that of divergent thinking. Woodworth (1938) identifies verbal fluency with problem-solving ability. Harootunian and Tate (1960) identify the factors of divergent thinking as related to systematic or logical reasoning. However, Harootunian (1966) also found that divergent thinking behavior was not related to reading achievement.

With a curriculum designed to emphasize both inquiry and involvement, will cognitive and affective behavior be changed? Is there a relationship between providing the strategies of inquiry in teaching science (i.e.: classifying, observing, using number relations and recognizing and using space/time relations) and specific cognitive and affective behaviors? Related research supports the expected dimensions of change for the selected criterion variables of problem-solving, perceptual closure, verbal fluency, ideational fluency, tested intelligence, attitude, attitude, and selectivity of perception.

THE STUDY

Sample:

The sample of subjects employed in the investigation consisted of 95 regularly enrolled members from a single elementary school in Austin, Texas. The subjects were selected by choosing every third student from an alphabetical list made up of class rosters of four fourth grade, three fifth grade, and four sixth grade classes.

Pretest IQ data on the subjects were taken from their school records, using their most recent scores. The range in scores was from 81 to 131 with 114 being the median for the group. The range in chronological age, also secured from school records, was from 105 to 145 months with 124.5 months as the median age.

The subjects, who had no recorded experience in a curriculum sequence which placed stress on strategies of inquiry in science, received five months of such experience followed by performance testing in the selected strategies of inquiry. Pre-post test data were secured on all criterion behaviors prior to and following the experiences with the strategies of inquiry in science.

The Instruments:

To assess specific behaviors of students in Grades 4, 5, and 6 the following instruments were used:

BEHAVIOR	INSTRUMENT
Verbal I.Q.	California Mental Maturity Test, 1963 S-Form, Level 2
Nonverbal I.Q.	California Mental Maturity Test, 1963 S-Form, Level 2
Total I.Q.	California Mental Maturity Test, 1963 S-Form, Level 2
Attending	STEP Listening Test, Forms 4A and 4B
Science Recall	STEP Science Test, Forms 4A and 4B
Science Problem Solving	TAB Science Test, Forms A and B
Verbal Fluency	Guilford Factor-Rhymes Test

BEHAVIOR	INSTRUMENT
Ideational Fluency	Guilford Factor-Common Situations Test
Perceptual Closure	Guilford Factor-Short Words Test
Reading Achievement	Metropolitan Achievement Test, Form A, Elementary Battery; Form A and Am, Intermediate Battery.
Language Achievement	Metropolitan Achievement Test, Form A, Elementary Battery; Form A and Am, Intermediate Battery.
Arithmetic Problem Solving	Metropolitan Achievement Test, Form A, Elementary Battery; Form A and Am, Intermediate Battery.
Attitude Toward Science	Semantic Differential
Attitude Toward Scientists	Semantic Differential
Performance in Strategies of Inquiry	(AAAS) Student Process Measure

FINDINGS

The relationship between the criterion variables of behavior and the selected strategies of inquiry in science were tested by multiple linear regression. The criteria and predictor variables were tested in relation to the following questions:

1. How reliable is a score indicating performance in a strategy of inquiry for predicting a particular behavior? For example, can performance in classifying reliably predict a student's ideational fluency?

2. Does a significant relationship exist between scores indicating performance in a strategy of inquiry and behavior change scores?

3. What is the magnitude of the equality of grade differences in the relationship between scores indicating performance in a strategy of inquiry and behavioral change scores?

Results of this analysis are presented in Tables 1, 2, and 3. The evidence indicates that performance in selected strategies of inquiry is correlated with those behavior factors associated with intelligence, divergent thinking, attending, science recall, reading, and attitudinal perception of the potency of "science". The strategy of inquiry which indicated the greatest number of correlations with behavioral change was "using numbers" followed by "classifying", "space/time relations", and "observing". Table 1 indicates probability levels for predicting this behavioral change. It is apparent that none of the strategies of inquiry can be used to predict behavioral change in all of the behavioral criteria.

From the evidence presented it appears that all of the selected strategies correlate significantly with the student's verbal and/or total IQ behavior. The strategy of "classifying" is correlated with attending behavior and with the behavior of ideational fluency.

TABLE 1

SUMMARY OF PROBABILITY LEVELS FOR THE PREDICTION OF BEHAVIORAL CHANGE BY THE STRATEGIES OF INQUIRY IN GRADES 4, 5, and 6

Behavior	Class.	Obs.	U.N.	S/T
IQ Verbal	$<.01$	$<.05$	$<.01$	$<.01$
IQ Total	$<.05$	n.s.	$<.05$	$<.05$
Attending	$<.05$	n.s.	n.s.	n.s.
Science Recall	n.s.	n.s.	$<.05$	n.s.
Verbal Fluency	n.s.	n.s.	$<.05$	n.s.
Ideational Fluency	$<.05$	n.s.	n.s.	n.s.
Perceptual Closure	n.s.	n.s.	$<.05$	n.s.
Reading	n.s.	n.s.	n.s.	$<.05$
Attitude to Potency of Science	$<.01$	$<.05$	$<.05$	n.s.

Class. = Classification
Obs. = Observing
U.N. = Using Number Relations
S/T = Space/Time Relations

NOTE: Change in the behaviors of nonverbal, IQ Science Problem Solving, Language Achievement, Arithmetic Problem Solving, and Attitude toward Scientists were not significantly predicted by the Strategies of Inquiry.

The strategy of "using numbers" is correlated with achievement behavior in science recall, with verbal fluency, and with perceptual closure. The strategy of "space/time relations" is correlated only with the behavior associated with reading. Of the selected strategies "classifying", "observing", and "using numbers" are correlated with the student's attitude toward the potency of science.

Further findings indicate limited evidence of significant interaction among grades between the behaviors associated with intelligence and divergent thinking and performance in the strategies of inquiry in science. (See Table 2) There appears to be no consistent pattern among grades. Further analysis of grade differences indicates that grades 4, 5, and 6 are not equally different with regard to behavioral change. (See Table 3) It is interesting to note that no significant differences appeared in the relationship between the strategies of inquiry and the behaviors associated with attitude, attending, and science problem solving. This suggests that grades 4, 5, and 6 may be equal with regard to these behaviors.

DISCUSSION

When one examines the correlations between the strategies of inquiry and behavioral change it is apparent that none of the strategies of inquiry can be used to predict behavioral change in

TABLE 2

SUMMARY OF SIGNIFICANT INTERACTIONS AMONG GRADES FOR THE RELATIONSHIP BETWEEN BEHAVIORAL CHANGE AND THE STRATEGIES OF INQUIRY IN GRADES 4, 5, and 6.

BEHAVIOR	CLASS.	OBS.	U.N.	S/T
IQ Verbal	<.01	<.01	n.s.	<.01
IQ Nonverbal	n.s.	n.s.	n.s.	<.05
IQ Total	<.01	<.01	<.01	<.01
Verbal Fluency	<.01	<.01	<.01	<.01
Perceptual Closure	<.01	<.01	<.01	<.01

Class. = Classification

Obs. = Observing

U.N. = Using Number Relations

S/T = Space/Time Relations

TABLE 3

SUMMARY OF SIGNIFICANT GRADE DIFFERENCES FOR THE RELATIONSHIP BETWEEN BEHAVIORAL CHANGE AND THE STRATEGIES OF INQUIRY IN GRADES 4, 5, and 6.

BEHAVIOR	CLASS.	OBS.	U.N.	S/T
IQ Verbal	<.01	<.01	<.01	<.01
IQ Total	<.01	<.01	<.01	<.01
Science Recall	<.05	<.05	<.05	<.05
Verbal Fluency	<.01	<.01	<.01	<.01
Ideational Fluency	n.s.	n.s.	n.s.	<.05
Perceptual Closure	<.01	<.01	<.01	<.01
Reading	<.01	<.01	<.01	<.01
Language Total	<.01	n.s.	<.05	<.05
Arithmetic Problem Solving	<.01	n.s.	<.01	<.01

Class. = Classification

Obs. = Observing

U.N. = Using Number Relations

S/T = Space/Time Relations

all of the behavioral criteria. Each strategy of inquiry may call for a different cognitive behavior and may be closely related to specific tests used in the study. For example, measuring a student's performance in "classifying" appears to be useful in predicting attending behavior. A reasonable inference can be drawn that there are similar cognitive behaviors in "classifying" and attending. One might conclude that the strategy of "classifying" is effective in sharpening perceptive selectivity. It can also be inferred that the measuring instruments are closely related.

Harootunian and Tate (1960) consider the divergent thinking behavior of ideational fluency to be the facility to call up ideas where quantity rather than quality is emphasized. The correlations between the strategy of "classifying" and ideational fluency may suggest that this strategy is stimulating a quantity of student ideas and/or concepts.

A possible interpretation of the correlations of the strategy of "using numbers" with behavior in science recall and in verbal fluency may be related to the close association of mathematics and science lessons. It appears possible that reinforcement of experimental background may enhance not only some informational and relational knowledge but stimulate confidence and the opportunity to verbalize such knowledge. The apparent association of "using numbers" with behavioral change in percpetual closure may be interpreted as suggesting that this strategy sharpens the student's ability to identify objects or concepts in spite of perceptual distractions.

Behavioral change in reading may be related to the strategy of "space/time relations". One possible inference from this relationship is that spatial discrimination and, consequently, reading behavior is improved. Another, and more potent, inference is that the students' interests are stimulated and their curiosities and motivations are increased to the extent that desire and consequent improvement in reading are the result.

It appears that behavioral change among the grades is not the same for all the criterion factors, i.e., younger children appear to change as much as older ones. The students do reflect an attitudinal change toward science and seem to see science as being more important as a result of five months of instruction.

The preponderance of negative regression slopes resulting from the analysis suggests that the higher the student's initial score on a particular behavior, the less change occurs in the student. In a similar manner, the higher the student's initial score on a strategy of inquiry, the less change can be expected or predicted in the criterion behavior.

Viewing actual change scores indicated that in many of the factors investigated, Grades 5 and 6 showed regressive tendencies. Gardner (1947) presents evidence that slow development in science occurs between Grades 5 and 11. Is there a relationship between the findings of this study and those of Gardner's study? If there is a relationship, does this suggest that in most abilities, skills, and attitudes there is less change as the child's age increases?

SUMMARY

From an examination of the learning situation one might hypothesize that if exposed to situations which focus on inquiry and student involvement, certain changes should occur in student cognitive and affective behaviors as a consequence of interacting with the strategies of inquiry of a curriculum. With a curriculum designed to emphasize both inquiry and involvement will cognitive and affective behavior be changed?

A review of the literature suggests that factors of cognitive behavior may include problem solving, perceptual closure, verbal fluency, ideational fluency, and tested intelligence. Affective behavior, though difficult to separate from cognitive behavior, may include attitude and selectivity of perception. The latter may be related to attending behavior. Both cognitive and affective behavior appear to be related to achievement.

Criterion variables of behavior were tested to determine their relationship to the strategies of inquiry of science. Analysis of this relationship by multiple linear regression produced answers to the following questions:

1. How reliable is a score indicating performance in a strategy of inquiry for predicting a particular behavior?
2. Does a significant relationship exist between scores indicating performance in a strategy of inquiry and behavioral change scores?
3. What is the magnitude of the equality of grade differences in the relationship between scores indicating performance in a strategy of inquiry and behavioral change scores?

Results of the analysis are summarized as follows:

1. It appears that none of the strategies of inquiry in science by themselves can be used to predict behavioral change in all of the behavioral criterion.

2. There is limited evidence of significant interaction among grades between the behaviors associated with intelligence and divergent thinking and performance in the strategies of inquiry.

3. No significant differences appeared in the relationship between the strategies of inquiry and the behaviors associated with

attitude, attending, and science problem solving. Grades 4, 5, and 6 may be equal with regard to these behaviors.

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