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ABSTRACT

This study compared the effects of two specific post-laboratory discussion strategies in science on the development of the four cognitive skills of observation, inference, verification and classification. The two strategies were: (1) teacher-dominated, in the form of organized lectures based on the data students had collected; and (2) student-dominated, in that students evaluated their own results and justified all inferences they made. The sample consisted of eight groups of sixth grade students, four from an urban school and four from a suburban school. The discussions were analyzed using the "Classroom Observational Record," and students' ability in the four skills were assessed using the "Inquiry Skill Measures." Analysis of variance indicated that strategy (2) resulted in a significantly greater gain in the quantity and quality of student inferences than did strategy (1). In the suburban school, strategy (2) was better than strategy (1) in developing observation, but the reverse was found in the urban school. No conclusions could be drawn concerning the skills of verification and classification. (Author/MM)

Discussion Strategies and Student Cognitive Skills

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Theoretical Framework

One of the major distinctions between many traditional science programs and teaching science by an inquiry method is that the latter puts a much greater emphasis on the processes of science (Van Deventer: 1966). These processes include such skills as observation, classification, inference, and verification. Teaching science through inquiry allows the child to manipulate and control phenomena directly in a way that requires explanations for observed inconsistencies. As Gagne (1963) has said, "what it is (inquiry) is a set of activities characterized by a problem-solving approach, in which newly encountered phenomena become a challenge for thinking." Referring to Suchman, Butts and Jones (1967) have said, "Suchman has analyzed in depth how inquiry is conducted by the Elementary School child. He has stated that in inquiry into a problem situation, a child (1) searches, (2) processes data, (3) discovers, (4) verifies." Butts and Jones (1967) themselves say, "These five activities (searching, processing data, discovering, verifying, assimilating-accommodating) are the specifics for a model of inquiry." There are a great many different ways of classifying these processes, ranging from the classical scientific method to descriptions of critical thinking and problem solving. Having children inquire and discover relationships in science is predicated upon the idea that they are acquiring certain skills as well as content.

Most of the current elementary school science projects emphasize inquiry, and stress the importance of the acquisition of skills by the children which will enable them to collect and process information leading to the evaluation of hypotheses. The child should be able to attempt explanations for phenomena, and then proceed to evaluate his explanations. The child should be able to perform such skills as observation, inference, classification, prediction, hypothesis formation, verification, and evaluation of hypotheses. To a considerable degree, the success with which a child can solve problems or process information depends upon his level of proficiency with these and other skills. The child must not simply create an explanation, but should be able to evaluate its feasibility or suitability as well.

The developmental psychology of Piaget (1964) also emphasizes the active interactions of students in the learning process. Piaget also stresses the importance of peer interaction throughout the entire learning process, as well as maximizing the direct experiences of students with phenomena. Bruner (1967) also believes that students should be active in the learning process interacting both with the phenomena and with other students. Experience should be direct and concrete at first, gradually becoming more abstract and symbolic as their abilities develop.

Suchman (1964) has incorporated many of the ideas of Piaget and Bruner into his Inquiry Development Program for science. The student is encouraged to experiment and work with materials in an effort to solve problems or inconsistencies that occur. These observed inconsistencies which do not fit into the existing conceptual framework of the student, lead the child towards accommodation

in his attempts to resolve the inconsistency or solve the problem. The teacher can encourage the processes of assimilation and accommodation, as well as the development of many of the inquiry skills, by employing specific types of discussion and questioning strategies.

A strategy which encourages students to process data and evaluate their explanations would place more of the responsibility for generalization and concept formation upon the students. Asking students to clarify, explain, and verify their explanations should be more effective in promoting active student involvement than would immediately accepting or rejecting an explanation when it is offered. A discussion strategy based on the ideas of Piaget and Bruner would emphasize the interaction of students with each other as they evaluate and analyze their explanations. The majority of the majority of the analyzing, evaluating, and verifying should be done by the students themselves, and not by the teacher in the form of organized lectures.

Method

The primary purpose of the investigation was to determine the effects of two specific post-laboratory discussion strategies in science with sixth grade children on four selected cognitive skills. The two discussion strategies were designated as probing or divergent, and non-probing or convergent. The four cognitive skills that were being investigated were the skills of observation, inference, verification, and classification.

The Sample

The sixth grade children selected to take part in this study were from two different school districts in and around Philadelphia,

Pennsylvania. The inner city school was in a district comprised of children of mixed racial background. The pupils were predominantly black and of lower middle class economic status. The other school was in the Philadelphia suburban township of Lower Merion. The pupils were predominantly white and of middle class economic status (United States Census Report: 1960).

The children in the suburban school could not be assigned at random to the treatment groups because of administrative conditions, so intact classes had to be used. Intact classes also had to be used at the inner city school, but some equalization of class size was necessary. The sixth grade population at this school consisted of three classes of thirty-five children and one class with fifteen students. In order to equalize the four sixth grade treatment groups, five children were selected from each of the first three classes and were assigned to this smaller class. This formed four treatment groups of approximately equal size. The type of treatment and the teacher were assigned at random to each of the eight treatment groups, four in each school.

Instructional Program

All eight groups, four in the inner city school and four in the suburban school, received similar programs of instruction for a period of eleven weeks. The amount of instruction and the type of material presented, with respect to content and laboratory experience, was carefully controlled so that all eight groups received similar pre-laboratory and laboratory experiences. Only the post-laboratory discussion strategy differed. The eleven [illegible] program was designed to cover topics from the areas of biology,

chemistry, and physics as well as to give the students practice with the skills of observation, inference, verification, and classification. Such topics as the behavior of mealworms, sounds, properties of powders, pendulums, air pressure, and germination and growth of seeds and plants were included.

Post-laboratory Discussion Strategies

The eight classes were subjected to two different types of post-laboratory discussion strategies. One was designated as a probing discussion and the other was designated as the non-probing discussion. In terms of J. P. Guilford (1957) the strategies might be called divergent and convergent discussions respectively. He says that in convergent thinking, " there is almost always one conclusion or answer that is regarded as unique, and thinking is to be channeled or controlled in the direction of that answer." Guilford contrasts this with divergent thinking where

> ... there is much more searching about or going off in various directions... divergent thinking ...(is)... characterized... as being less goal bound. There is freedom to go off in different directions... Rejecting the old solution and striking out in some new direction is necessary, and the resourceful organism will more probably succeed.

In accordance with these two definitions, the two discussion strategies were designated to emphasize either a single correct answer to a problem situation, or to emphasize a diversity of possible solutions or possible ways of seeking solutions. Each of the teachers involved in the investigation conducted both discussion strategies in the two treatment schools.

In the non-probing discussion, the children were encouraged to collect data relating to a problem situation, but the processing

of the data and the interpretation were done by the teacher. The children were not given the opportunity to devise alternate explanations for phenomena, but rather were told the "correct" answers by the teacher in the form of organized lectures. The children performed experiments in which the data were collected through observations and measurement, but all of the data processing involving the formation and explanation of hypotheses was done by the teacher. Data which did not agree with the so-called correct answer was rejected as wrong and was not left open for the students to investigate.

On the other hand, the probing discussion strategy specifically focused on inconsistencies that arose out of the observations of the children and encouraged them to explore ways of resolving these discrepant occurrences. If two children reported opposite bits of information as a result of an experiment, these differences were not explained away by the teacher, but rather became the focus for further discussion and experimentation by the children themselves. The teacher using this second discussion strategy would accept all observations, require evidence and/or clarification of all inferences made, and ask the students to evaluate verbally any tests suggested for the inferences.

The two discussion strategies that were being investigated, probing and non-probing, evolved as a result of using the Classroom Observational Record devised by Reynolds, Abraham, and Nelson (1971) to analyze the types of discussions that were being used by elementary school teachers in their science lessons. It was found that these science discussions generally seemed to be of two types. a teacher-dominated discussion, where the teacher did most of

the analyzing, concluding, and testing; the other, a student-dominated discussion, where the students did most of the analyzing, concluding, and testing. As a result of these observations, the probing and non-probing discussion strategies were evolved and formulated.

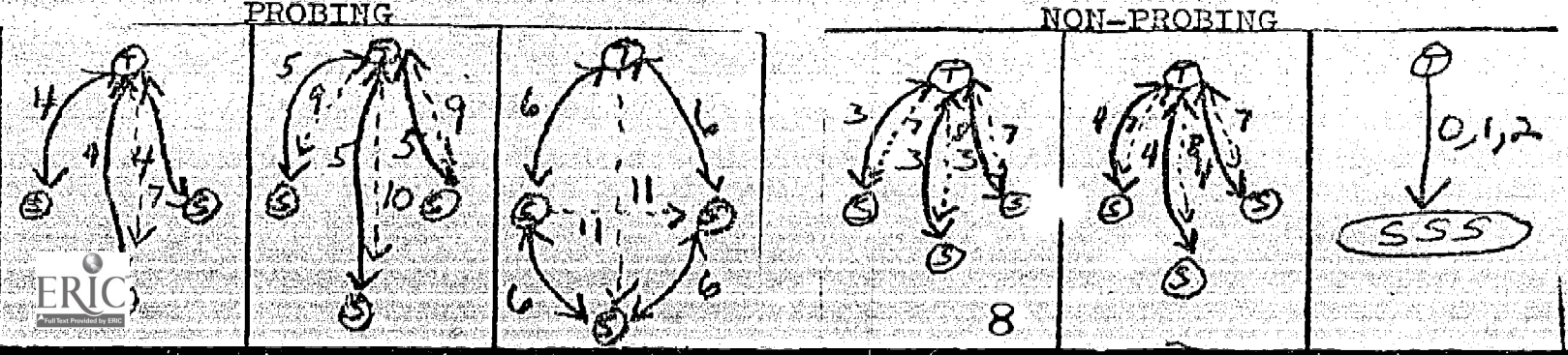
In terms of the categories of the COR the non-probing discussion strategy would generally be characterized by a large amount of teacher Lecturing (1). Soliciting moves would consist mainly of Recall questions (3) and Data Collecting questions (4). There would be few, if any, Data Processing questions (5) or Data Evaluation (6) questions. The Responding moves would be either Accepting (7) or Rejecting (8), and there would be little or no Clarifying (9), Calling for evidence (10), or Calling on another student (11) moves.

The probing discussion strategy would be characterized by Soliciting moves in categories (5) and (6), and Reacting moves in categories (9), (10), and (11). There would be much less teacher Lecturing (1) or Rejecting (8) of student responses. The two discussion strategies would not differ greatly in the number of moves in categories (2), (3), (4), (3'), (4'), or (7).

Figure 1 illustrates the discussion strategies in terms of the paradigms developed by Nelson, Reynolds, and Abraham (1971).

Figure 1

The Discussion Strategies



Experimental Design and Statistical Analysis

The basic design of the investigation is outlined in TABLE 1.

TABLE 1

Experimental Design

Pretest	Instructor	Discussion Strategy	Post-test
	SCHOOL A --	PHILADELPHIA INNER CITY	
ISM*	Teacher 1	Non-probing discussion	ISM**
	Teacher 2	Probing discussion	
	Teacher 2	Non-probing discussion	
	Teacher 1	Probing discussion	
	SCHOOL B --	PHILADELPHIA SUBURBAN	
ISM*	Teacher 1	Non-probing discussion	ISM**
	Teacher 2	Probing discussion	
	Teacher 2	Non-probing discussion	
	Teacher 1	Probing discussion	

* Form A of the Inquiry Skill Measures

** Form B of the Inquiry Skill Measures

Thirteen post-laboratory discussions for each class were audio-taped. Using a Table of Random Numbers (Edwards: 1966), four of each class' audio-taped discussions were selected for analysis. Each discussion was encoded and analyzed using the COR to detect how closely the above discussion strategies were followed. The proportion of statements made for each category of the COR were subjected to a 2 X 2 X 2 ANOVA, having as factors School, Teacher, and Discussion Strategy, in order to determine how closely the discussion models were followed.

To determine whether the discussion strategies were effective in producing significant gains for the class' use of selected cognitive skills, fifteen children from each class were selected at random from an alphabetized list. These children were given as a pre-and post test the Inquiry Skill Measures(ISM), an instrument designed to detect changes in students' use of the four cognitive skills of observation, inference, verification, and classification. (Nelson and Abfaham: 1971) The four cognitive skills were defined as follows:

Observation- the ability to gather data through the use of the five senses

Inference - the ability to project into an unexplored area from observations in an explored field on the assumption of continuity

Verification - the ability to test the validity of an inference

Classification - the ability to form groups having some common specified observed property

Test-Retest reliability and validity of the Inquiry Skill Measures was determined on a separate and equivalent student population. The pre-and post test scores for the fifteen individuals tested within a class were averaged and used to compute class mean gain scores. The results were used as the dependent variable in a 2 X 2 X 2 factorial design having as factors School, Teacher, and Discussion Strategy.

Results

Analysis of the COR data showed that the teaching strategies were followed closely as they were defined, but in the case of the probing discussion strategy, the tactic of getting the students to evaluate inferences was not applied as frequently as had been

planned. In terms of COR categories, this meant that the frequency of (6) and (6') moves was less than had been anticipated. These data are summarized in TABLE 2.

TABLE 2

Summary of Category Frequency Using The Classroom Observational Record

Category	Percent in Non-probing Discussion	Percent in Probing Discussion
Teacher Moves		
Reviewing (0)	3.8	7.9
Informing (1)	62.7	15.3
Directing (2)	2.2	0.2
Recall Questions (3)	9.4	12.5
Data Collecting Questions(4)	3.0	4.0
Data Processing Questions(5)	0.1	15.7
Data Evaluation Questions(6)	0.0	3.0
Accepting Responses (7)	7.7	6.4
Rejecting Responses (8)	3.8	0.1
Clarification Responses (9)	2.3	8.5
Calling for Evidence (10)	0.0	8.9
Calling on Another Person(11)	0.0	0.1
Calling Someone by Name (N)	3.9	6.0
Repeating a Response (R)	3.0	7.6
Student Moves		
Recall Responses (3')	62.7	34.8
Data Collecting Responses(4')	23.0	6.1
Data Processing Responses(5')	10.0	51.3
Data Evaluation Responses(6')	0.0	7.9

In addition to analyzing the frequency of occurrence of the COR categories, the number of specific tactics were analyzed in each of the two discussion strategies. A chi-square statistic was computed for each of the designated tactics to determine whether

the occurrence in one of the strategies was significantly greater than in the other discussion strategy. The chi-square statistic was tested for significance at the 05 percent level. The criteria for the tactics and the results are summarized in TABLE 3.

TABLE 3

Summary of Tactic Frequency Using the Classroom Observational Record

Tactic Description	Criteria in COR Categories	Non-probing Discussion	Probing Discussion	Chi-square level
Teacher Lecturing	At least 5 Consecutive (1)	146	17	.001
Recall Questioning	At least 4 Consecutive (3)	55	33	not significant
Data Collecting Questioning	At least 4 Consecutive (4)	6	2	not significant
Data Processing Questioning	At least 4 Consecutive (5)	1	55	.001
Data Evaluation Questioning	At least 4 Consecutive (6)	0	1	not significant

This table indicates that for the tactics of Teacher Lecturing and Data Processing Questions the two discussion strategies were applied as they were defined. The same is also true for the tactics of Recall Questioning and Data Collecting Questioning since the two discussion strategies do not differ with respect to the frequency of these tactics.

In spite of a 29 point difference in class mean Intelligence Quotient between the two schools (82 Urban and 111 Suburban) there was no significant difference in the class mean gain score on any of the inquiry skills for the factors of school and teacher.

The COR data were analyzed to ascertain whether the two discussion strategies were actually applied as they were defined. The results of the analysis of variance of the COR data indicated that :

1. For a one-tailed test at the .05 level there were significantly more Informing and Rejecting moves in the non-probing discussion. The $F_{(max.)}$ test, however, indicated that there was a heterogeneity of variance, so the significance is in doubt.

2. For a one-tailed test at the .05 level there were significantly more Data Processing Questions (5), Clarifying Responses (9), Calling for Evidence (10), and Calling on Another Person (11) in the probing discussion strategy.

3. For a two-tailed test at the .05 level there was no significant difference between the two discussion strategies with respect to the number of moves in Reviewing (0), Directing (2), Recall Questions (3), Data Collecting Questions (4), Accepting Responses (7), and Repeating Responses (R).

4. For a two-tailed test at the .05 level there was no significant difference for the following moves for either Teacher or School : Reviewing (0), Informing (1), Directing (2), Recall Questions (3), Data Collecting Questions (4), Data Processing Questions (5), Accepting (7), Rejecting (8), Clarifying (9), Calling for Evidence (10), Calling on Another Student (11), and Repeating a Response (R).

The results of the analysis of variance of the difference scores on the Inquiry Skill Measures can be summarized as follows:

1. For a two-tailed test at the .05 level there was a significantly greater gain on inferences made by the probing discussion group than by the non-probing strategy.

2. For a two-tailed test at the .05 level there was a significantly greater gain in the accuracy of the inferences made by the probing discussion group than by the non-probing discussion group.

3. For a two-tailed test at the .05 level there was significant interaction between school and discussion strategy on the number of observations made. Analysis of the significant main effects indicated that the probing strategy was more effective in the suburban school, and the non-probing strategy was more effective in the urban school.

Based on these results the following conclusions were drawn :

1. When one is teaching science in an inquiry fashion to sixth graders and one's objective is to increase the quantity and quality of inferences, then the probing strategy is to be preferred over the non-probing strategy.

2. If one's objective is to increase the quantity of observations made, then the probing strategy is to be preferred in a suburban school, while the non-probing strategy is to be preferred in an urban school.

Due to certain problems in methodology, no specific conclusions could be drawn about the effect of the post laboratory discussion strategies on children's learning of the skills of verification and classification.

Limitations

The limitations of the investigation can basically be divided into several distinct groups. They are concerned with either the sample, the criterion instruments, the experimental procedure, or the instructional program.

Since the overall instructional unit was the intact class, the study would have had more generalizability if overall random assignment could have been used in initially forming the classes. If more than two teachers had been used, the results would also

have been more generalizable. Also, because the major criterion instrument- the Inquiry Skill Measures, is relatively new, it lacks reliability data obtained from other samples with different investigators. The ISM also may have been insufficiently reliable for detecting differences for all of the variables studied. The lack of appropriate equivalent instruments prevented the obtaining of any true measure of concurrent validity. Had this investigation been conducted over a longer period of time, or had the instruments been used previously in other studies, there might have been some data related to predictive validity.

In terms of the experimental procedure, it would have been advantageous to have continued the period of instruction beyond the eleven week period. The additional time might have further increased the amount of experimental effect.

The instructional program could have been expanded to further emphasize the development of the higher order, i.e., more complex, cognitive skills, such as verifying and classifying. Analysis of the COR data showed that in the probing strategy approximately eight percent of the student responses were related to data verification, while very few of their responses were directly concerned with the skill of classification. For further study of the discussion strategy effect, it would have been valuable to increase the conscious attention paid to these two skills.

The use of the Classroom Observational Record was one of the strongest aspects of the investigation, because it provided some external measure of how the treatment effect was actually applied. The data showed that the two discussion strategies, probing and non-probing, were actually applied similarly by both teachers in

each of the two schools. The data also revealed that there was a significant difference with respect to the questioning techniques as actually applied with the probing and non-probing discussion groups. Thus, the experimental treatment was applied as defined, in similar manner, by both teachers in both schools.

Implications

This investigation indicates that classroom verbal interactions between teachers and students can have definite effects on the development of selected skills which are considered to be important factors in the newer, more process oriented, science curricula. While it is difficult to draw generalizable conclusions, in this study at least, the teacher questioning strategy was significant with respect to the development of children's ability to draw inferences from observed data. Both suburban and inner city children increased their ability to suggest inferences when they were exposed to a probing, rather than a non-probing discussion strategy.

The COR provides the teacher with an opportunity to assess the types of verbal interactions occuring in the classroom. Unlike many other forms of Interaction Analysis, the COR concerns itself primarily with the cognitive levels of questions and responses by both teachers and students. By using the COR to analyze the types of discussions that occur in the classroom, the teacher can effectively evaluate the types of interactions which take place, in terms of their cognitive levels. Often, teaching objectives and teaching practices may be more dissimilar than many teachers would like. The COR affords the teacher the

opportunity to evaluate his questioning strategies with respect to the specific cognitive skills they seek to develop within the students.

The results off this investigation indicate the importance that discussion strategies can have on the development of selected cognitive skills in science. It must be remembered, however, that this investigation has explored one nareow aspect of the entire inquiry process, namely, post-laboratory discussion strategies. Though it has provided some useful information with regard to student cognitive skill development, there is a great need for more experimental research into other aspects of classroom interactions. A more thorough research foundation is needed before the objectives and promises of many of the newer elementary school science curricula can be substantiated.

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