DOCUMENT RESUME

ED 134 591	95	SP 010 787

AUTHOR	Clark, Christopher M.; And Others
TITLE	A Factorially Designed Experiment on Teacher Structuring, Soliciting, and Reacting. Research and Development Memorandum No. 147.
INSTITUTION	Stanford Univ., Calif. Stanford Center for Research and Development in Teaching.
SPONS AGENCY	National Inst. of Education (DHEW), Washington, D.C.
PUB DATE	Nov 76
CONTRACT	NE-C-00-3-0061
NOTE	746p.; Pages 448-450 of original document are copyrighted and therefore not available
EDRS PRICE	MF-$1.33 HC-$39.51 Plus Postage.
DESCRIPTORS	*Classroom Techniques; Cognitive Tests; *Educational Research; Educational Strategies; *Effective Teaching; Elementary School Teachers; *Experimental Programs; Experimental Teaching; Learning Characteristics; Response Style (Tests); Student Reaction; Teacher Attitudes; *Teacher Behavior; *Teaching Methods; *Teaching Styles; Teaching Techniques

ABSTRACT

This experiment on teacher effectiveness focuses on the causal effects of teacher behavior within the classroom recitation. Each of four teachers used one of eight treatments in teaching an ecology course to eight sixth-grade groups. The treatments differed at two levels of teacher structuring, soliciting, and reacting. High structuring consisted of reviewing, stating objectives, outlining the lesson, indicating important points, and summarizing. Low structuring was the absence of these behaviors. High soliciting consisted of asking a large percentage of "thought" questions and waiting about three seconds or more after a student's response before calling on a second student. Low soliciting asked a low percentage of "thought" questions and waited only a short time after response. High reacting consisted of praising correct responses, providing reasons for wrong answers, and prompting. Low reacting consisted of using neutral feedback after correct response and not providing reasons for wrong answers. Tests were given to the students before and after the experiment. Results suggest that uncontrolled and unmeasured teacher behaviors and characteristics influenced student achievement and attitude. Analyses indicate that student perceptions mediated the effects of structuring and reacting. A follow-up study showed that merely reading the materials contributed substantially less to student achievement than the combination of reading and teaching. Statistical tables are included. Five appendixes outline the elements of the nine-lesson unit used in the experiment. (Author/JD)

Stanford Center for Research and Development in Teaching
School of Education, Stanford University
Stanford, California

Research and Development Memorandum No. 147

A FACTORIALLY DESIGNED EXPERIMENT ON TEACHER STRUCTURING, SOLICITING, AND REACTING

Program on Teaching Effectiveness, SCRDT

November 1976

Published by the Stanford Center for Research and Development in Teaching, supported in part as a research and development center by funds from the National Institute of Education, U. S. Department of Health, Education, and Welfare. The opinions expressed in this publication do not necessarily reflect the position, policy, or endorsement of the National Institute of Education. (Contract No. NE-C-00-3-0061.)

CONTRIBUTORS

The design, execution, analysis, and writing of the report of this study were performed by Christopher M. Clark, N. L. Gage, Ronald W. Marx, Penelope L. Peterson, Nicholas G. Stayrook, and Philip H. Winne. These persons prefer that references to the report be made as follows:

Program on Teaching Effectiveness, SCRDT. A factorially designed experiment on teacher structuring, soliciting, and reacting (R&D Memorandum No. 147). Stanford, Cal.: Stanford Center for Research and Development in Teaching, 1976.

4

INTRODUCTORY STATEMENT

The mission of the Stanford Center for Research and Development in Teaching is to improve teaching in American schools. Current major operations include three research and development programs--Teaching Effectiveness, The Environment for Teaching, and Teaching and Linguistic Pluralism--and two programs combining research and technical assistance, the Stanford Urban/Rural Leadership Training Institute and the Hoover/Stanford Teacher Corps Project. The ERIC Clearinghouse on Information Resources is also a part of the Center. A program of exploratory and related studies provides for smaller studies not part of the major programs.

SCRDT's Program on Teaching Effectiveness is a program of research and development on teaching funded by the National Institute of Education. The major mission of the Program on Teaching Effectiveness is to develop and test improved ways of teaching for both novices and experienced teachers. The Program is particularly interested in testing new ways of helping experienced teachers improve their work.

This report describes in detail the results of an experiment conducted by the Program on Teaching Effectiveness in public school classrooms during the spring of 1975. A brief preliminary report of the experiment appeared as Occasional Paper No. 7 in October 1975.

ACKNOWLEDGMENTS

The research reported herein is the work of many persons. The coauthors wish to express thanks to the following for their help, cooperation, and encouragement:

--The experiment's teachers and classroom observers--Gayle Detweiler, Patricia English, Jane Gildea, Sandra Noreen, Meredith Papagiannis, Dorothy Rosenthal, Nancy Rowswell, Michele Scott, Tanya Suter, and Constance Wright.

--Lyn Corno, for her work on the path analysis section of this report; Alexis Mitman, for her efforts in collecting data and writing the comparison of the read-only treatment with the recitation strategy; Dale Schunk and Elaine Baskin, for their help with pretesting and post-testing; Jean Ziebron and Kim Young, for their first-class secretarial and administrative support throughout, from the recruiting of teachers to the typing of the final report.

--Our predecessors in the use of highly scripted teaching behavior in experiments on teaching, particularly Graham Nuthall and Meredith Gall.

--The Far West Laboratory for Educational Research and Development, whose staff members gave freely of advice and encouragement.

--The teachers, principals, and school district personnel who cooperated so thoroughly with us during the course of the study. They were

Los Altos School District:
Loyola Elementary School
Principal: Mr. Richard Liewer
Teacher: Mr. Ceccetti

Portola Elementary School
Principal: Dr. Lloyd Andrews
Teachers: Mr. Dully
Ms. Tierney
Mr. Wallingford

Santa Rita Elementary School
Principal: Mr. William Jones
Teachers: Mr. Montgomery
Mr. Elliott

Portola Valley School District:
Corte Madera Elementary School
Principal: Ms. Mary Ostrom
Teachers: Ms. Damm
Mr. Draggett
Ms. Mund
Ms. Westbrook

Palo Alto Unified School District:
Barron Park Elementary School
Principal: Ms. Janet Fieock
Teachers: Mr. Godsey
Ms. McCall

Fairmeadow Elementary School
Principal: Mr. Louis Parente
Teachers: Ms. Lewis
Mr. Sanford

Garland Elementary School
Principal: Dr. Thomas Steege
Teachers: Mr. Carey
Ms. Meaders

Green Gables Elementary School
Principal: Mr. Lloyd Cunningham
Teachers: Mr. Crozier
Ms. Saperstein

Ortega Elementary School
Principal: Mr. Robert French
Teacher: Mr. Wise

--Finally, the children, too many to name, who helped us by being themselves.

ABSTRACT

This experiment determined the causal effects of teacher behavior within the classroom recitation. Each of four teachers used one of eight treatments in teaching ecology to eight sixth-grade groups.

The treatments differed at two levels of teacher structuring, soliciting, and reacting. High structuring consisted of reviewing, stating objectives, outlining, signaling transitions, indicating important points, and summarizing; low structuring omitted these behaviors. High soliciting consisted of asking approximately 60 percent higher-order (thought) questions and waiting three seconds or more after a student's response; low soliciting consisted of asking approximately 15 percent higher-order questions and waiting less than three seconds. High reacting consisted of praising correct responses, providing reasons for wrong answers, prompting, and writing student ideas on the board; low reacting consisted of lower or opposite values of these behaviors.

Before teaching began, the students took aptitude and attitude tests. Then followed nine lessons of about 40 minutes each. During each lesson, the students first read a few pages of text. Then came the classroom recitation. After the nine days, and again three weeks later, the students took essay and multiple-choice tests of their achievement and inventories of their attitudes toward ecology and perceptions of the teaching.

Analyses of covariance, with vocabulary or attitude pretest scores as the covariate, indicated that low soliciting yielded higher achievement on several subscales of the multiple-choice posttest. Low structuring and low reacting, together, yielded lower posttest achievement. There were no significant effects on the posttests of essay achievement and attitude toward ecology. The retention measures showed similar main and interaction effects.

The four teachers had different effects despite the control of teacher behavior and subject matter. The main and interaction effects of the teachers suggested that uncontrolled and unmeasured teacher behaviors and characteristics influenced student achievement and attitude. Path analyses indicated that student perceptions mediated the effects of structuring and reacting. Aptitude-treatment interaction (ATI) effects suggested that teaching methods better for some students were worse for others. A follow-up study showed that merely reading the materials contributed substantially less to student achievement than the combination of reading and teaching.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

9

CHAPTER

TABLE OF CONTENTS (continued)

LIST OF TABLES

TABLE

LIST OF TABLES (continued)

TABLE

TABLE

TABLE

LIST OF TABLES (continued)

TABLE

LIST OF TABLES (continued)

TABLE

LIST OF FIGURES

Chapter I. JUSTIFICATION OF THE EXPERIMENT

As this is written, millions of classrooms in the United States and elsewhere are being taught by the "recitation method." In that method, teaching consists of a relatively rapid exchange of questions by the teacher and answers by the student. These questions and answers are occasionally preceded by some "structuring" on the part of the teacher--discourse in which the teacher attempts to set the framework of the subject matter and the perspective from which it will be examined. Further, the students' answers may be followed by "reactions" from the teacher--statements in which the teacher praises or corrects the student's response or asks for further responses.

By this characterization, the recitation method consists of teacher structuring, teacher soliciting (primarily questioning), pupil responding, and teacher reacting. The formulation was originally made by Bellack, Kliebard, Hyman, and Smith (1966) in a study of the teaching of a unit on international trade in 15 eleventh-grade classes in New York City. Since then, that analysis of the recitation has been found (Bellack, 1976) useful in about 35 related studies describing teaching at every grade level from elementary through college; in subjects as varied as reading, English, mathematics, business, science, teaching, and nursing; in six other countries (Sweden, Finland, Australia, West Germany, Canada, and Japan); and in such varied settings as individualized instruction, mathematics in "open" elementary school classrooms, and early education programs. In all these studies, the pattern of structuring, soliciting, responding, and reacting was found to occur in clearly defined ways, at a fairly rapid pace, cyclically patterned. Teacher soliciting, pupil responding, and teacher reacting (or teacher soliciting and pupil responding) constituted the principal sequences of pedagogical moves.

The recitation is not only ubiquitous; it has already been much studied. Hundreds of investigations have described the kind and frequency of the many different kinds of events that occur in such teaching. In addition, these studies have often dealt with the relationship between those events and what students learn. Why does the recitation deserve still further study in a day when many alternative strategies of teaching have been proposed? In this chapter we offer some justification for further study of the recitation method and point out the need for complex experimentation on that method. In subsequent chapters we describe the methods, results, and implications of our experiment.

Longevity of the Recitation Strategy

Classroom recitation has been with us for many years. According to Hoetker and Ahlbrand (1969), the recitation in the form sketched above was occurring in classrooms observed in 1908 and 1912. It has been the kind of teaching studied in most of the investigations conducted since research on teaching began, slowly in the 1920s and 1930s, and at an ever-increasing rate beginning in the 1940s. Of the many scores of studies reviewed by Rosenshine (1971) and by Dunkin and Biddle (1974), most, by far, have been concerned with teaching by the recitation method.

That the recitation has persisted seems evident to any casual visitor in American schools or any reader of descriptions of teaching in the United States and the rest of the world. For example, Goodlad and Klein (1970) and their coworkers found the recitation clearly predominant when they observed teaching in 260 classrooms ranging from kindergarten to grade three throughout the United States in the late 1960s. They remarked that

> At all grade levels, the teacher-to-child pattern of interaction overwhelmingly prevailed. This was one of the most monotonously recurring pieces of data. The teachers asked questions and the children responded usually in a few words and usually correctly--that is, with the response approved or acknowledged as correct by the teacher. It is fair to say that teacher-to-child interaction was the mode in all but about five percent of the classes [p. 51].

Challenges to the Recitation Strategy

Yet, especially during the last decade, the classroom recitation method has been widely challenged. Critics have charged that the teacher using this method faces serious, perhaps insurmountable, obstacles to good teaching. In particular, the individualization of instruction according to students' abilities, interests, and prior achievement is regarded as extremely difficult in the classroom recitation approach.

To achieve greater individualization, teachers have been urged to adopt such alternatives as tutoring by nonprofessional aides or peers of the students, programmed instruction, teaching machines, computer-assisted instruction, token economies based on behavior modification models of teaching, open classrooms, and mastery learning approaches. These alternatives have been added to older ones, such as the discussion method and the seminar, which have always been regarded as highly useful in secondary and higher education. Thus, at the height of the teaching machine movement, Skinner declared that "Holding students together in a class is probably the greatest source of inefficiency in education" (1961, p. 387).

Alternative Strategies as Supplements

But the classroom recitation has not yet been shown to be completely replaceable by those alternatives. The demise of teaching machines was memorialized in a program entitled "Bidecennial afterthoughts on the teaching machine, 1956-1976" at the 1976 convention of the American Psychological Association; at that meeting former leaders of the movement, such as Susan M. Markle, noted the virtual disappearance of teaching machines from the educational scene.

Programmed tutoring has been found to be an effective and feasible supplement to the classroom teacher's work in various subject matters and grade levels (Ellson, 1976). But it has not been proposed as a major replacement of the classroom recitation; it merely serves to supplement the main teacher's efforts for, say, 15 to 60 minutes of the school day.

The same can be said of individual seat work, independent study, self-guided study, computer-assisted instruction, and programmed textbooks, as well as open classrooms, humanistic approaches, and mastery learning approaches. All of these have value as alternatives to the classroom recitation for part of the school day and part of the educational objectives. But they have not yet been adopted as major replacements for what Bellack, Goodlad, and their colleagues have found to be so overwhelmingly prevalent.

Systems of Individualized Instruction

Whole new systems of individualized instruction have also been developed--Individually Prescribed Instruction (IPI), the Program for

Learning in Accordance with Needs (PLAN*), and Individually Guided Education (IGE), among others--requiring school reorganization. Because these systems have been proposed as replacements of the recitation strategy, let us look at them in some detail. In these systems students work for a substantial part of each school day on instructional modules, preceded by thoroughgoing diagnostic procedures used to determine what each student will do in the light of his or her abilities, needs, interests, and previous achievement. Each module is relatively short, lasting from a day to perhaps two weeks. The student's work on the module is evaluated by criterion-referenced achievement tests. The student moves ahead to the next module, or does remedial work on the preceding one, according to his performance on this test. The system is designed to permit students to advance at their own rate, working alone or in small groups for substantial parts of every school day.

What is the evidence on the effectiveness of these systems? One recent publication (Talmage, ed., 1975) brought together descriptions of these systems by the persons who have led in their development. Let us consider what these authors have offered on the evaluation of their systems and also the conclusions of independent evaluations, such as those by the Educational Products Information Exchange (EPIE) (1974).

Klausmeier (1975, pp. 77-78), reporting on the effectiveness of IGE, stated that a higher percentage of pupils in IGE schools than those in convential schools achieved mastery of 23 skills. Fewer of the IGE pupils mastered six skills, and equal percentages in the two groups mastered one skill. In both groups the means for pupils taught with the Wisconsin Design for Reading Skill Development were higher.

Similarly, the self-concepts of the pupils in the IGE schools were more favorable than those of pupils in the traditional schools. The pupils' attitudes toward fellow pupils in IGE schools were more favorable than in traditional schools. The two groups were about the same in their attitudes toward teachers and instruction and in school morale.

With respect to the evaluation of IGE, however, EPIE (1974, p. 33) reported that "the summative evaluations are narrowly conceived, experimentally and instrumentally inadequate, and not very useful to consumers."

*The asterisk is used by Westinghouse Learning Corporation to label its version of the system originally developed by the American Institutes for Research in the Behavioral Sciences.

Similarly, an extensive tryout in the Austin, Texas, schools led to the conclusion that "Despite some positive effects demonstrated on objectives in the affective area, the lack of positive results on achievement lead to the conclusion that the IGE program should be discontinued" (Austin Independent School District, 1975, p. 1).

Glaser and Rosner (1975) provided no information on the effectiveness of IPI as compared to conventional modes of education in improving achievement of cognitive or social-emotional objectives. EPIE (1974) stated that "the data are particularly mixed on the use of IPI with different populations and in different settings. In our estimation, the designs of studies are unable to document whether different findings are a result of the program or of the implementation of the program" (p. 60). More recently, Fesler, Guidubaldi, and Kehle (1976) have reported that IPI classes in the Primary Education Project of an elementary school were significantly superior to control classes on various standardized achievement tests.

With respect to PLAN*, Flanagan, Shanner, Brudner, and Marker (1975) reported an improved self-concept among students, particularly minority students, and more favorable attitudes toward school. But improvements in achievement were hard to detect during the first year of operation, perhaps because everyone was still learning to work within the new system. The report went on to say that, in the second and third years, greater academic gains became evident for PLAN* students in comparison with students in traditional instructional programs. The longer a student is in PLAN*, it concluded, the greater the gain. In 33 comparisons, PLAN* students at Hicksville, New York, performed significantly better than non-PLAN* students. Nonetheless, EPIE (1974) stated that "there are no conclusive studies to indicate that the achievement of PLAN* students is greater or less than that of students in other programs" (p. 20).

Briggs (1975, p. 170) commented on the evidence regarding systems of individualized instruction. He stated that formative evaluations had been made extensively, that some summative evaluations had been made and more are planned, and that some programs are in stages of development that make final evaluation premature. Scriven (1975, p. 202) commented similarly:

> Now, most of these projects say that they have done well in field tests, but I am skeptical. One might argue that, in most cases, the educational significance of the actual gains, even using a

> no-treatment or old-treatment control group, has been very slight, a fact often buried beneath the incantations of statistical significance. I have already argued that the use of such a control is inadequate; there must also be a comparison with other possible adoptions, notably those already available. But let us look at the crucial factor for many prospective users of these systems--cost. The level of cost analysis being done on them is (I believe I am up to date on this) exceedingly primitive, especially with regard to indirect costs, and always noncredible, that is, always done or controlled by the staff of the project.

Subsequently, Scriven makes a statement that brings us to our own justification for further research on the classroom recitation strategy:

> Individualization has, of course, always been with us. Indeed, that is what the one-room schoolhouse we have been racing away from was all about. The hoped-for breakthrough was envisaged as the result of systematically managed individualization in many dimensions with specially developed materials. What is not clear is whether, for the same amount of money, group activities of a fairly conventional (single-paced) kind could not have matched even the most optimistic gains claimed by the systems [p. 204].

Even in the case of PSI (the Keller Plan, or Personalized System of Instruction), Scriven raises questions about space, time, and staffing--all of which would have to be substantially reorganized if PSI were to replace more traditional systems. Further, Scriven notes that the problems presented by cheaters and procrastinators, the social dimensions of class attendance, the significance of releasing test items in advance, and cost-benefit analyses are all matters that PSI has neglected. Finally, Scriven concludes:

> From the moral point of view, to pick up another perspective, the student should (ideally) be treated as an individual, that is, he should not be shackled to the learning pace of other members of the class, should not be advanced without having grasped the prerequisites for the next lessons, should have a chance to ask questions without the risk of looking foolish in front of his peers, should be informed of exactly the kind of question and answer that he or she is expected to be able to handle, should get feedback on progress regularly, and should not have to attend lectures if learning is as effective and more convenient via other inputs.... But to find a general solution, one must pick up great differences in cost, for which large sums of money are not likely to be available now, and one must solve serious unsolved problems in the system....
>
> Thus to encourage strongly the use of PSI or any other system as providing students with their rights is very superficial since no one has a clear right to increase local taxes by, say, 25 percent to improve his or her education [pp. 208-9].

We would raise similar questions about mastery learning approaches (Block & Burns, in press; Bloom, 1968).

In short, as Eash (1975) states: "The superiority of total systems of individualization over piecemeal approaches to individualization has not been empirically demonstrated" (p. 3).

The Recitation Strategy in Individualized Instruction

In any case, systems of individualized instruction often call upon the teacher to interact with students in ways closely akin to the classroom recitation. In IGE (Klausmeier, 1975, p. 54), one teacher may excel as a tutor, another in small-group activities, and still another in large-group activities. Instructional programing in IGE includes "adult-led large group activities" among the alternatives. Similarly, in IPI, "students may be taught by lecture, by workbooks, by group discussion, by group projects, or by teaching machines" (Glaser & Rosner, 1975, pp. 92-93). Finally PLAN* often entails "discussion groups, working in pairs, small-group instruction, large-group instruction, and the like" (Flanagan et al., 1975, p. 146).

Thus, even within these systems of individualized instruction, teacher-student interaction similar to that in the classroom recitation occurs some of the time. Just how much it occurs cannot be ascertained in the reports cited above. But knowledge concerning teacher effectiveness in the classroom recitation should also contribute to the improvement of systems of individualized instruction.

The Present Experiment and Input-Output Research

Current doctrine concerning the significance of teacher variables stems in large part from what we call input-output research. One major example of such research is the Equal Educational Opportunity Study (EEOS), better known as the Coleman Report (Coleman et al., 1966). Related to that study are Inequality by Jencks and his coworkers (1972), and studies and reviews by such writers as Averch and others (1972) and Hanushek and others (1972). All these studies have led to the conclusion that teacher variables account for only a minor portion of the variance between students, classrooms, and schools in student achievement. But the Program on Teaching Effectiveness (1973), among other critics, has questioned the relevance of these input-output studies to the effects of teacher variables. There are three basic objections, deriving from the nature of the independent variables used in those studies, the nature of their dependent variables, and the correlational rather than experimental method used in estimating the relationships between the two kinds of variables.

The Independent Variables

First, the independent variables in these studies have consisted of teacher characteristics in the form of such variables as the teacher's verbal ability, the teacher's localism (Does he teach in the area where he grew up?), and the teacher's social-class background as indexed by his mother's educational level. Whatever may be the promise of other teacher characteristics, those of the kind just named should not be regarded as justifying any strongly-held convictions about the importance of teacher variables.

Input-output studies from which such shattering implications for the importance of teacher variables have been drawn, have treated the teaching process as one essentially enclosed in the classical "black box." That is, they have disregarded what goes on in classrooms. They must accordingly leave open the question of what can be learned when classroom processes, especially teacher behavior, are carefully examined in detail. Thus, many writers, including Gagné (1970) and Bloom (1972), have urged that the teacher characteristics of the input-output studies be replaced with variables reflecting events that impinge directly on the student's behavior as a learner. The present study manipulated teacher behaviors to determine their effects, and it also dealt with behavioral characteristics of teachers as perceived by students.

The Dependent Variables

Second, as dependent variables the input-output studies have used students' vocabulary, verbal ability, or other variables measured by tests primarily indicative of general intelligence. As is well known, such tests have been designed to be relatively impervious to the influence that schools exert. Indeed, they are quite distinct from achievement tests, which are designed to measure the capabilities and dispositions that classroom teaching is explicitly intended to influence. But achievement tests seem much more appropriate to the purpose of assessing the effects of teacher variables. Hence the present study used measures of educational outcomes explicitly relevant to what was being taught.

Correlational vs. Experimental Methods

Third, the input-output studies have relied on correlational rather than experimental methods. Causal influence can perhaps be inferred from some types of nonexperimental studies, such as cross-lagged panel correlations or path analyses, or studies in which extraneous variables can be held constant statistically. But no one questions the greater value of causal inferences based on experiments (see, e.g., Gilbert & Mosteller, 1972, pp. 372, 373). In experiments, the independent variables are manipulated in their application to randomly assigned subjects, rather than merely observed as they occur under natural conditions.

The correlational, or survey, study may have advantages in representativeness or ecologial validity. It also has great value for exploring the potential causal value of large numbers of variables with great economy in a single investigation. But when experiments are feasible, they are almost always superior as a basis for statements about the causal effects of teacher variables, and teacher behaviors in particular, on student achievement. Hence, the present study was designed to be a true experiment, incorporating manipulation of independent variables and random assignment of subjects.

Many writers have already made this point. Thus Rosenshine and Furst (1973, p. 122) described a "descriptive-correlational-experimental loop" which culminates in "experimental studies in which the significant variables obtained in correlational studies are tested in a more controlled situation." Similarly, Dunkin and Biddle (1974, p. 446) recommend that "Process-process and process-product experiments should be encouraged, but preferably for the validating of crucial relationships previously discovered in field surveys or with strong theoretical justification." Good, Biddle, and Brophy (1975, p. 58) urged that researchers "move from correlational designs to experimental designs" to achieve greater certainty. And Gilbert and Mosteller (1972) entitled their paper "The Urgent Need for Experimentation" in discussing what should follow the Coleman Report.

But single-variable experiments of the kind already conducted (e.g., Gall, Ward, Berliner, Cahen, Crown, Elashoff, Stanton, & Winne, 1976; Nuthall & Church, 1973) are inadequate to the complexities of classroom teaching. They can reveal only main effects, and it seems reasonable to entertain the possibility that interaction effects occur. Such interaction effects would mean that the effect of one teacher behavior variable changes as the value of another teacher variable changes. Thus high structuring might have one effect in the presence of high soliciting and another effect in the presence of low soliciting. It was to make possible the revelation of such interaction effects that the present experiment was especially intended.

A further purpose of the present investigation, one which emerged as an afterthought, although an important one, was to determine the degree to which classroom teaching had different effects on achievement and attitude from what might be obtained through merely giving students germane reading matter. Can students learn as much and like a subject as well if they read, without the intervention of a teacher via a classroom recitation? This important question--and the subordinate question of which components of the recitation make a difference--was thus also investigated.

A final justification for experiments, as against correlational studies, is that they can show the feasibility and desirability of the changes in teacher behavior with which teacher education programs can be concerned. Without evidence on causal efficacy, of the kind that only experiments can yield, we cannot know the degree to which certain kinds of teacher behavior should be regarded as attainable and desirable objectives of teacher education. Correlational results can only suggest what may be desirable in teacher education. Experiments can demonstrate and establish, with a necessarily high degree of operational definition, what such programs should aim at.

Summary of the Justification

In short, the present experiment on the recitation strategy seemed necessary for the following reasons:

1. The recitation strategy is still predominant in American elementary and secondary schools, and knowledge concerning causal factors in its effectiveness should therefore be valuable.
2. The evidence concerning the effectiveness of proposed replacements for the recitation strategy, including IPI, IGE, and PLAN*, is still inconclusive.
3. Even within these major proposed reorganizations of schooling, teacher-student interaction similar to the classroom recitation will occur.
4. Input-output research on teacher variables has used teacher characteristics rather than teacher behaviors as independent variables, student intelligence rather than instruction-relevant achievement as dependent variables, and correlational rather than experimental methods as the basis for the causal inferences drawn.
5. Previous experiments have manipulated only one dimension of teacher behavior at a time. Thus they have neglected the possibility of interaction effects such that the effect of one dimension might be influenced by the simultaneous variation of another dimension.
6. Previous studies have not compared teaching effects with those of students' mere reading of the text materials.

Accordingly, an experiment on the classroom recitation strategy was carried out by the Program on Teaching Effectiveness of SCRDT in the spring of 1975.

Chapter II. THE EXPERIMENT

What kind of experiment was desirable and feasible for examining teacher behaviors in relation to student achievement and attitudes within the recitation strategy of teaching? This chapter describes in detail the experiment carried out--its treatments, design, curriculum, subjects, training manipulations, instruments, and procedures. But first we offer a brief overview.

Overview

The experiment was unique in manipulating three clusters of teacher-behavior dimensions considered significant in the light of the many correlational studies of teacher behavior in relation to student achievement. Those studies, reviewed by Rosenshine (1971) and Dunkin and Biddle (1974), had yielded results that taken individually were often if not usually nonsignificant statistically. But the statistical nonsignificance of these results should not be taken too seriously. Most of the studies were based on only 10 to 40 teachers. Further, the correlation of any single teacher-behavior dimension with student achievement should not be hypothesized to be more than about .25 or .30. For these two reasons, most individual studies of single dimensions of teacher behavior yield statistically nonsignificant results. But there is reason to believe that the combined results of studies of single dimensions of teacher behavior will be statistically significant, as when "vote-counting" (Light & Smith, 1971) or tests of the significance of the combined results (Jones & Fiske, 1953) are applied.

The behavior dimensions derived from the correlational studies were clustered into three composite teacher-behavior variables within the classroom recitation strategy of teaching. As Bellack and others (1966) have shown, teachers' behavior in the classroom recitation strategy can be subdivided into structuring, soliciting, and reacting. (A fourth kind of classroom behavior, responding, is performed mainly by students.) Within the category called "structuring," a subsidiary list of behaviors was specified and manipulated. The same was true of the categories termed "soliciting," and "reacting."

The design of the experiment is shown in Figure 1. Each of the three teacher-behavior dimensions was manipulated in a 2 x 2 x 2 factorial design. Four experienced teachers received rigorous training over a two-week period in ways of manipulating their own behavior to conform to each of the eight resulting patterns. Each teacher then taught eight different groups, one by each of the eight methods. The teaching was conducted in 20 sixth-grade classes, 12 of which were divided at random into two halves. Each of the 32 half-classes consisted of about 13 students. Each half-class was taught nine 45-minute lessons constituting a curriculum unit on ecology especially prepared for the experiment.

Before the teaching was begun, the students responded to a series of aptitude tests and attitude inventories. Then, after the teaching was finished--that is, on the tenth day of the class meetings--the students responded to multiple-choice and essay tests measuring various cognitive and affective outcomes of the teaching. Finally, three weeks later, the students were tested again with similar or parallel instruments.

Thus, the experiment's purpose was to ascertain the degree to which high and low levels of structuring, soliciting, and reacting influenced student achievement and attitudes. It also provided a basis for estimating the interaction effects of the three independent variables. Interaction effects indicate that the effect of manipulating one kind of teacher behavior depends on the level of one or more other kinds of teacher behavior. Thus significant interaction effects would mean that the manipulation of only one kind of teacher behavior at a time, which has previously been characteristic of experimental and most correlational research on teaching, yields an incomplete estimate of the effects of teacher behaviors on student achievement and attitudes. In short, this experiment could estimate the causal significance of teacher behaviors for student achievement in ways more rigorous and complex than those previously used. That it was conducted within the classroom-recitation strategy makes its results potentially significant for the main body of classroom work.

The Treatments: Their Derivation and Definition

The eight variations of the recitation strategy used in this experiment can be characterized as eight treatments to which different groups

Time Block	District	School	Class	Half-Class	Treatment*	Teacher
		A	a	1	HHH	II
				2	LHH	I
		A	b	3	LHL	IV
FIRST	I			4	HHL	III
		A	c	5	LLH	II
				6	HLH	IV
		A	d	7	LLL	III
				8	HLL	I
		B	e	9	HHH	I
				10	LHH	II
		B	f	11	LHL	III
				12	HHL	IV
SECOND		C	g	13	LLH	IV
		C	h	14	HLH	II
		D	i	15	LLL	I
	II	D	j	16	HLL	III
		E	k	17	HHH	III
		H**	l	18	LHH	IV
		E	m	19	LHL	I
				20	HHL	II
		F	n	21	LLH	I
				22	HLH	III
THIRD		F	o	23	LLL	II
				24	HLL	IV
		G	p	25	HHH	IV
				26	LHH	III
		H	q	27	LHL	II
	III			28	HHL	I
		I	r	29	LLH	III
		I	s	30	HLH	I
		I	t	31	LLL	IV
				32	HLL	II

Fig. 1. Design of the experiment.

*Treatment designations indicate high (H) and low (L) levels of structuring, soliciting, and reacting, respectively.

**School H is in District III.

of students were exposed. By training teachers to vary systematically the way in which they carried out the recitation strategy, we could determine whether different ways of using that strategy have different effects on student learning.

As already noted, the experiment rests on the analysis of teacher behavior formulated by Bellack and others (1966). That analysis broke classroom behavior down into "moves" called structuring, soliciting, responding, and reacting. Structuring consists of telling the students what is going to happen next--what they are going to be dealing with, talking about, and handling, and how the material is to be dealt with. Soliciting is equivalent to question-asking, except that the question need not always be asked in a complete sentence, in interrogatory form, or in a verbal statement. Soliciting can be indicated by intonations in declarative sentences, for example, or by incomplete sentences that students are expected to complete.

Responding refers to the answering of questions, which Bellack and others (1966), Hoetker and Ahlbrand (1969), Power (1971), and many others have found to be performed about 90 percent of the time by students. In the last-mentioned study, for example, Power recorded the frequency and percentages of the four different kinds of classroom "moves" in schools in Queensland, Australia. He found that teacher responding constituted only 1.8 percent of all the moves, while pupil responding constituted 30.8 percent. Thus, because teacher responding is so infrequent, this dimension of classroom behavior was excluded from the present experiment on teacher behavior.

Finally, reacting is what the teacher does after the student has provided a response. It can take the form of praise, criticism, waiting silently, correction, asking the same student another question, and so on.

The Structuring Treatment

Bellack's structuring-soliciting-reacting trichotomy has greater significance than it is credited with by Bellack himself and by other investigators (e.g. Power, 1971) who have adopted it in their own studies. Indeed, as Gage and Berliner (1975) have shown, Bellack's concepts embrace many, if not most, of the scores of teacher-behavior dimensions that have been the subject of more than a hundred correlational studies of teacher behavior and student achievement. Thus under Bellack's concept of structuring, Gage and Berliner grouped four teacher-behavior dimensions: the rate of teacher initiation and structuring, signal giving, organization, and directness.

After reviewing other studies, Dunkin and Biddle (1974) concluded that "a moderate use of teacher initiation and structuring is (weakly) associated with high pupil achievement" (p. 34). Similarly, they wrote:

> Often in other chapters we have had to conclude either that process-product evidence was missing or that the relationships reported were weak ones. This latter is also true for the two findings generated by Bellack concerning the <u>rate of teacher cycles</u> and the use of <u>initiation</u> and <u>structuring</u> by the teacher. It is <u>not</u> true for the four findings reported by Wright and Nuthall, however. In fact, some of the strongest findings they reported concerned features of tactical-sequence use. It was found that teachers who used...<u>episode-terminal structuring</u> all generated greater achievement in pupils.... Taken together, these findings would appear to suggest that good teaching is characterized by simple patterns of teacher-pupil interaction and by frequent structuring summaries. However, Wright and Nuthall caution us that their findings were generated against the criterion of the test of low-level knowledge and may not do justice "to the full range of educational objectives in which most teachers are interested" [<u>ibid</u>., p. 336].

Another aspect of structuring is termed "signal giving." It occurs when teachers signal somehow that one part of a lesson has ended and another has begun. Crosson and Olson (1969) found in a study of two 10-minute lessons in the sixth and twelfth grades, with 6 and 35 teachers respectively, that such signals of transition correlated positively with achievement. They also found that the teacher's tendency to signal, or emphasize, words to be learned correlated positively with achievement. Similarly, Pinney (1969) found that the frequency with which beginning teachers used "verbal markers of importance" in two 45-minute social studies lessons at the eighth- and ninth-grade level correlated positively with student achievement.

Organization is a more abstract dimension of teaching that requires a higher degree of inference on the part of observers. Accordingly, it is usually measured by ratings made by students or observers. Such ratings have been found to be positively correlated with student achievement by Fortune, Gage, and Shutes (1966), Fortune (1969), and Belgard, Rosenshine, and Gage (1971). Similarly, in a large sample of high school physics classes, negative correlations with student achievement and interest were consistently found for students' ratings of disorganization (Anderson & Walberg, 1968; Walberg, 1969a, 1969b; Walberg & Anderson, 1968). What determines students' impressions that a lesson is organized was not examined by these studies. But it is reasonable to hypothesize that organization is enhanced by structuring moves, including signal giving, emphasizing words or concepts to be learned, and providing verbal markers of importance.

Finally, it is plausible that teacher structuring can be reflected in the amount of teacher talk. Nine correlational studies of this variable were brought together by Rosenshine (1971) and by Dunkin and Biddle (1974). Perhaps because the numbers of teachers in these studies were small, ranging from 15 to 31, with a median of 17, none of the correlations was statistically significant. But they were consistently positive and low. Gage and Berliner summed up the data as follows:

> Four of the eight correlations between teacher talk of one kind or another and student achievement equal or exceed .29; only one is negative. It seems safe to conclude that there tends to be a low positive relationship between teacher talk and student achievement. If teacher talk is assumed to consist largely of the teacher-structuring component of the classroom recitation, we can infer that higher degrees of teacher structuring are associated with higher student achievement. But it should not be overlooked...that there probably exists an optimum point, above which teacher structuring and talk inhibit student growth in some areas.... But the low positive correlations between teacher talk and achievement suggest that most teachers do not reach the point of excessive teacher talk, where achievement begins to drop off. Rather, the correlations suggest that teachers can talk too little to foster maximum achievement [1975, pp. 694-695].

Thus, for the purposes of our experiment, it was stipulated that high structuring would consist of reviewing the main ideas and facts covered in the lesson; stating objectives at the beginning of the lesson; outlining the lesson content; signaling transitions between parts of a lesson; indicating important points in a lesson; and summarizing the parts of the lesson as the lesson proceeded. Low structuring was defined as consisting of the absence of these teaching behaviors.

The Soliciting Treatment

Most of the many studies of teacher soliciting or questioning behavior deal with the frequency of questions, the cognitive level of questions, or the degree to which the teacher redirects questions and probes. On the frequency of questions, the evidence summarized by Rosenshine (1971, pp. 159-70) and Dunkin and Biddle (1974, p. 134) consists of seven studies. Of these, five yielded positive correlations (.44, .44, .13, .11, and .07) with student achievement, and two yielded negative correlations (-.19 and -.05). Thus the evidence favoring the teacher's asking more questions is weak and not highly consistent. The same is true of the evidence on the "number of interchanges" between teachers and students. This variable probably resembles the frequency of questions in reflecting teachers' attempts to involve students in intellectual interaction. Of the eight studies of this kind brought together by Rosenshine (1971, pp. 160-63), the results were almost equally divided between positive correlations (four studies) and negative correlations (three studies), with one study yielding both positive and negative correlations.

What about evidence on the cognitive level of questions? This variable refers to the degree to which a teacher's questions call merely for (a) knowledge, or the recall or recognition of information previously received, or (b) "thinking," that is, processing the information for application, evaluation, analysis, synthesis, and other higher-order cognitive processes of the kind identified in the Taxonomy of Educational Objectives (Bloom et al., 1956). How does the amount and proportion of higher-order cognitive questions asked by the teacher relate to the level of student achievement? Higher-order questions may have other purposes, such as arousing curiosity and stimulating discussion, but their effect on achievement must still be considered important.

The evidence indicates that effect to be weak and inconsistent. The Rosenshine and Dunkin-Biddle reviews brought together eight correlational studies. Of these, two yielded some evidence of a positive relationship between amount of higher-order questioning and student achievement; five yielded weak negative relationships, and one yielded no relationship. Both reviews omitted a study by Ladd and Andersen (1970). In a correlational study of 40 th-grade classes in earth science, they found a highly significant superiority in the achievement of students taught by teachers above the median in asking higher-order questions over students taught by teachers below the median. The difference occurred on tests consisting of higher-order questions as well as on tests consisting of lower-order questions.

Winne (1975) reviewed the experimental studies on the subject. Apart from finding many methodological flaws, he presented evidence that can be summarized as follows:

1. Four studies yielded no significant or interpretable difference between the achievement of students taught with a relatively higher number or proportion of higher-order questions and those taught with a relatively lower number or proportion of such questions (Martikean, 1973; Ryan, 1973, 1974; Savage, 1972).
2. Three experiments favored lower-order questions (Lynch et al., 1973, studies A and B; Rogers & Davis, 1970).
3. Two studies favored higher-order questions (Aagaard, 1973; Buggey, 1971).

The best controlled experiment on the cognitive level of teacher questions is the one recently conducted by Gall, Ward, Berliner, Cahen, Brown, Elashoff, Stanton, and Winne (1976). Each class was randomly divided into four recitation groups. Each recitation group then received one of three soliciting treatments or an art-activity treatment. The soliciting treatments varied in proportion of higher-order and lower-order questions as follows: Treatment 1 consisted of 25 percent higher-order and 75 percent lower-order questions; Treatment 2 consisted of 50 percent higher-order and 50 percent lower-order questions; Treatment 3 consisted of 75 percent higher-order and 25 percent lower-order questions. The results of the experiment indicated a U-shaped relationship between percentage of higher-order questions and achievement on an information test. In all cases, student groups in the 50 percent higher-order treatment had considerably lower average achievement than the groups in the other two soliciting treatments. Generally, student groups in the 25 percent higher-order treatment outperformed groups in the 75 percent higher-order treatment on both knowledge and higher-order achievement measures, although the absolute differences between mean scores were small. Thus low or high percentages of higher-order questions were more effective than moderate percentages of these questions in building students' recall of information about a specified curriculum. These findings help explain the inconsistent results of previous experiments on teacher questions, which compared high or low levels of higher-order questions but did not consider moderate levels.

Previous studies had investigated only the "main effects" of the cognitive level of teachers' questions. Whether similar findings would be obtained if this variable was manipulated along with other dimensions of teacher behavior, such as teacher structuring and reacting, was a possibility that remained to be dealt with. There were other reasons for further research on the subject, too. Many educators have had what Dunkin and Biddle would label a strong commitment in favor of raising the cognitive level of teachers' questions; minicourses aimed at training teachers to do this have been developed. The literature on teaching by the discovery method and reflective thinking (Metcalf, 1963; Snook & Nuthall, 1973) implies that thinking rather than mere recall should be emphasized in classroom discourse. Finally, the research has been fairly consistent (Dunkin & Biddle, 1974, p. 241) in showing that higher-order questions elicit higher-order responses from students. Thus such questions can be justified on the plausible premise that practicing higher-level cognitive processes is necessary to acquire higher-level cognitive skills and habits.

Another aspect of soliciting is wait-time--how long the teacher waits after asking a question before repeating the question, calling on another student, or saying anything. Rowe (1974) found that a wait-time of at least three seconds tended to have a variety of beneficial effects on students' responses, as compared with a wait-time of less than three seconds. These effects were:

1. The length of response increases.
2. The number of unsolicited but appropriate responses increases.
3. Failures to respond decrease.
4. Confidence, as reflected in decrease of inflected [question-like tones of voice] responses, increases.
5. Incidence of speculative responses increases.
6. Incidence of child-child comparisons increases.
7. Incidence of evidence-inference statements increases.
8. The frequency of student questions increases.

9. Incidence of responses from students rated by teachers as relatively slow increases.
10. The variety in types of moves made by students increases [*ibid.*, p. 81].

A second kind of wait-time refers to how long the teacher pauses after a student response or comment. The typical reaction of a teacher comes very quickly, within one second. Rowe has found that increasing the second kind of wait-time also has the beneficial effects listed above.

In our experiment *high soliciting* was defined as consisting of asking a relatively large proportion, approximately 60 percent, of higher-order questions and 40 percent lower-order questions. Higher-order questions were in turn defined, in accordance with current terminology, as questions that required the student to respond with mental processes beyond Knowledge as defined in the *Taxonomy of Educational Objectives* (Bloom et al., 1956). Such questions would require the student to process information in some way rather than merely recognize or recall it. The student would thus perform such cognitive operations as application, interpretation, evaluation, and synthesis. In common parlance, higher-order questions are "thought" questions, and lower-order questions are "fact" questions. High soliciting also consisted of the teacher's waiting in silence a relatively long time (three seconds or more) after asking a question (to give the student a chance to respond), after a student response (to encourage elaboration on the part of the student), and before calling on a second student.

Low soliciting consisted of the teacher's asking approximately 15 percent higher-order questions and 85 percent lower-order questions. It also consisted of the teacher's waiting in silence a relatively short time (less than three seconds) after asking a question, after a student response, and before calling on a second student.

The Reacting Treatment

As already noted, reacting behaviors are those that occur after a student's response. Gage and Berliner (1975, pp. 702-11) classified teachers' reactions according to how soon they occur and whether they are positive, negative, or facilitative.

Positive reactions can take the form of praise or acceptance of student ideas. Praise needs no clarification—it takes such obvious forms as the teacher's saying "Good!" "Great!" "Fantastic!" The variable has frequently been investigated. Dunkin and Biddle (1974, pp. 121-22) and Rosenshine (1971, pp. 64-70) brought together 13 interpretable correlational studies of the relationship between frequency of teacher praise and student achievement. Of these, eight yielded positive coefficients of correlation, with a median of about .27, and six yielded negative coefficients, with a median of about -.27. One explanation of these inconsistent results is that the praise was routine and mechanical, rather than contingent on the correctness of the student's response. When praise was made contingent in this way by Hughes (1973) in an experiment with seventh-grade classes in nature study, the students who received thanks and praise for correct answers, support for improving incorrect answers, and urging or mild reproof when it was warranted, achieved more than students in the same class who received little more than a statement of the correct answer. Similarly, Bernhardt and Forehand (1975) found that praise was more effective with preschool children when the response being praised was "labeled" so that children were made aware of the behavior for which they were being praised. Praise was less effective when it was "unlabeled" or contained no reference to the behavior being praised. Thus Gage and Berliner (1975) summarized their review of the reviews on praise as follows:

> All in all, we find some slight indication that praise, especially when made contingent on the quality of the student's response, tends to be positively related to achievement. Teachers should yield to their inclinations to say, and otherwise communicate, favorable reactions to their students' responses. At least at the elementary level, where most of the research has been done, teachers will probably do little harm, and are likely to do more good, if they distribute praise generously [p. 705].

Use of student ideas is another kind of positive teacher reaction to a student response. It may consist of acknowledging, modifying, applying, comparing, or summarizing what has been said or suggested by a student. Use of an idea is considered to be a favorable reaction because it suggests to the student that the teacher thinks his or her idea is worthwhile and should be taken seriously. Gage and Berliner (1975), in summarizing the reviews, identified nine interpretable studies pertaining to this question. Eight studies yielded positive correlations, and only one yielded a negative correlation. It seems likely, then, that use of student ideas during teaching is associated with higher achievement and more positive student attitudes toward the teacher.

Negative reactions consist of the teacher's use of criticism and disapproval. This variable seems to be negatively related to student achievement with some consistency. According to Gage and Berliner (1975), of the 16 interpretable studies of the relationship between the teacher's use of criticism and disapproval and student achievement, 13 yielded a negative relationship (median r = -.32) and 3 yielded a positive relationship (median r = .16). Thus the evidence indicates that the relationship between frequency of teacher criticism and student achievement is usually negative. But which is cause and which is effect? Does more frequent criticism by the teacher cause lower student achievement? Or does lower student achievement cause the teacher to criticize students more? To settle the question of causation, experiments are needed. Unfortunately, training teachers to dispense criticism and disapproval, a behavior suspected of having harmful effects on student achievement, would be unethical. An ethical alternative would be to train teachers to react neutrally to student responses. Neutral reactions might include "Okay," "Correct," and "All right." Such reactions are relatively nonevaluative but provide students with information about the correctness of their answers. There is little correlational evidence on the relationship between neutral teacher reactions and student achievement, but the results of the aforementioned experimental study by Hughes (1973) are pertinent. As already noted, Hughes found that students who were given contingent praise performed significantly better on an achievement test than students who received little more than a statement of the correct answer.

Facilitative teacher reactions include (a) providing reasons for judging a student response to be incorrect; (b) prompting by providing a hint when a student response is incorrect or incomplete; (c) probing or repeating the question to the same student when a student response is incomplete or incorrect; (d) redirecting the question to another student; and (e) repeating the correct answer. Behaviors like these were found to be positively related to student achievement by Wright and Nuthall (1970). Two other studies (Soar, 1966; Spaulding, 1965) found a positive relationship between "probing" and student achievement. But "probing" in these studies appeared to be more than just the simple repetition of the question; it apparently included giving encouragement and perhaps even giving the student a hint (prompting).

Gage and Berliner (1975) concluded that though studies of these kinds of facilitative reaction variables have not been repeated, and the evidence is merely suggestive, "these structuring reactions make sense" (p. 710). In particular, it would seem that probing accompanied by prompting would be more effective than probing alone. In addition, providing a reason for judging a student response to be incorrect would be more effective than not providing a reason. Furthermore, it seems important that teachers inform students when a response is incorrect so that the incorrect response is not learned.

High reacting was defined in the present study as consisting of the following cluster of teacher behaviors:

praising correct responses;
saying "No" when a student response was judged to be incorrect, and providing a reason for the incorrectness;
prompting by providing a hint when a student response was incorrect or incomplete;
writing correct student responses on the chalkboard;
redirecting the question to a second student after prompting has failed to elicit the answer from the first student;
giving the correct answer after prompting and redirecting have failed to elicit the correct answer from the students.

Low reacting was defined conversely as consisting of the following kinds of behavior, considered to represent the opposite or the absence of the foregoing list:

giving neutral feedback after a correct student response;
saying "No" when a student response was judged to be incorrect and not providing a reason for the incorrectness;

<u>probing</u> or repeating the question without providing cues or hints to the same student who has just furnished an incomplete or incorrect response to the question;

<u>redirecting</u> the question to a second student after probing has failed to elicit the correct response from the first student;

<u>giving the correct answer</u> after probing and redirecting have failed to elicit the correct response from the students.

The Factorial Design

As already indicated, the independent variables were manipulated in a complete factorial design. The three independent variables (structuring, soliciting, and reacting), each at two levels (high and low), yielded eight treatment variations (see Table 1). Moreover, each of the four especially trained teachers taught each of the eight variations of the recitation strategy to different groups of students. Thus the full factorial design included teachers as a fourth independent variable.

TABLE 1

Levels of Structuring, Soliciting, and Reacting in Eight Variations of the Recitation Strategy

Variation	Structuring	Soliciting	Reacting
1	HIGH	HIGH	HIGH
2	HIGH	HIGH	low
3	HIGH	low	HIGH
4	HIGH	low	low
5	low	HIGH	HIGH
6	low	HIGH	low
7	low	low	HIGH
8	low	low	low

The factorial design made it possible to estimate both the main effects of each of the independent variables and their interaction effects. An interaction effect is said to occur when the effect of one independent variable depends at least in part on the value of another. An interaction between structuring and soliciting, for example, would mean that the effect of the level (high or low) of structuring changes when it is accompanied by a certain level (high or low) of soliciting. If there were a significant interaction between these two variables, then the effect of the structuring variable could be increased (or decreased) by the presence of high or low soliciting.

When an interaction effect occurs, the effect of the two independent variables taken together is not merely additive. Suppose that high structuring as opposed to low structuring made a difference of two points in mean achievement, and that high soliciting as opposed to low soliciting also made a difference of two points. Then the absence of any interaction effect would mean that the mean achievement of a group taught with high levels of both structuring and soliciting would differ by four points (two plus two) from the mean achievement of a group taught with low structuring and low soliciting. But if there were a significant interaction between structuring and soliciting, then the difference in mean achievement between the high structuring-high soliciting group and the low structuring-low soliciting group would not be four points but something greater or less, since the effect of the structuring variable would have been changed by its interaction with the effect of the soliciting variable.

Thus an interaction effect means that the effect of one independent variable cannot be predicted without regard to the value of another. For example, a statement such as "High soliciting produces more achievement than low soliciting" would need to be qualified by a clause such as "when accompanied by a high level of structuring."

Since teaching is such a complex process, it seems plausible and even probable that interaction effects between various teacher behaviors do occur. As we have already mentioned, we chose a factorial design for our experiment because it permits the examination of interaction effects. So far as we know, no previous experiment with teacher-behavior variables has manipulated more than one variable at a time or had a factorial design.

The Curriculum

Curriculum materials used in research on teacher variables should have several features. First, they should build indirectly on students' previous classwork and study. Second, they should be flexible enough to be used with more than one variation of a teaching strategy. Third, because teaching is likely to occur over several days, the curriculum should provide continuity over several lessons to avoid confounding the assessment of the teaching variables with curriculum variations. Finally, the curriculum should be interesting to the students and appropriate to their broader educational objectives.

In view of these considerations, the subject matter chosen for our experimental curriculum was the science of ecology. A curriculum in ecology could draw upon the content and cognitive processes learned in previous elementary school science courses. The subject afforded opportunities for using the different variations in teaching behavior we wanted to investigate. Daily lessons on ecology could be integrated to develop broader scientific concepts over a period of several days. Finally, the subject of ecology is an important and attractive one for elementary school students to study.

Sources

Ecology lessons to be taught over a period of nine days were developed with the assistance of a consultant in science education and environmental education, Dr. Stanley Cummings. The basis for the curriculum was a similar set of lessons, developed by Meredith Gall and Kenneth Crown at the Far West Laboratory for Educational Research and Development, for an experiment on teacher questioning (Gall et al., 1975). The last lesson was adapted by Gall et al. from the Science Curriculum Improvement Study (1971) and further revised by us. Beyond these sources, the following works were used in writing the curriculum: William Andrews's Guide to the Study of Terrestrial Ecology (1974), E. J. Kormondy's Concepts of Ecology (1969), Barry Commoner's The Closing Circle (1971), and the Biological Sciences Curriculum Study (green version, 1973).

In addition to the curriculum, the teachers were provided with two books for enriching their knowledge and understanding of the subject: An Island Called California by Elna Bakker (1972), and Introduction to the Natural History of the San Francisco Bay Region by Arthur C. Smith (1959).

Organization

The curriculum was designed both to convey important facts concerning ecology and to show how scientific information is developed into broader scientific concepts. Hence it contained both factual and conceptual material. The nine daily lessons were organized as follows:

Lesson 1: An introduction to the idea of a relationship as it is used in science, and an array of facts that would become a foundation for later lessons.

Lessons 2-3: The nature of energy and its flow through ecosystems.

Lesson 4: The role of matter in ecology.

Lesson 5: An integration of the material presented in lessons 1-4, with emphasis on the relationships between energy (lessons 2-3) and matter (Lesson 4).

A logical division occurred in the curriculum at this point, corresponding to the end of the first week of teaching. The second week (lessons 6-9) focused on living things in ecology and how they interact.

Lesson 6: Populations of living things.

Lesson 7: Communities composed of populations.

Lesson 8: Ecosystems as interactive combinations of living and nonliving components of the world.

Lesson 9: Review and application of the material covered in lessons 1-8 through consideration of a concrete example of human interaction with an ecosystem over several centuries.

Presentation

Following a pattern commonly used in elementary schools, the curriculum materials were presented in two ways. First, each day the students read a prose passage of three to five double-spaced typewritten pages containing basic information on that day's topic, including illustrations and graphs; this material served as an introduction to the lesson. These materials are contained in Appendix A. The reading material was available to the students only during the opening five minutes of the lesson, after which it was taken away. Second, the teacher presented information orally while using one of the eight variations of the recitation strategy.

The recitation sessions, regardless of which treatment they represented, were intended to build on and extend the facts and concepts presented briefly in the reading material.

The teachers were provided with lesson scripts--almost as specific as the scripts of plays--to use in conducting their recitation teaching. These scripts served to control to a high degree the material actually presented to the students during each lesson. Each script contained identical information, though it also provided for the variations in structuring, soliciting, and reacting called for in the experiment. Thus the content presented to students in a given lesson remained the same, regardless of which treatment variation was being used.

The lesson scripts took the form of 8 1/2 x 11 sheets divided into three columns. (Appendix B contains the master lesson plans for lessons 1 through 9, from which all of the eight treatment variations may be reconstructed.) The left-hand column contained the sentences the teacher would say in the structuring process; the middle column, the questions to be asked by the teachers in soliciting; and the right-hand column, the cues for the teacher to use in reacting. The teachers were trained to follow these scripts verbatim when possible or to use equivalent paraphrases. This training ensured that the content presented for a given lesson by different teachers would be nearly identical and that the treatment variations would be delivered as similarly as possible by the four teachers. During the actual teaching, the teachers held the scripts in their hands and referred to them as a lecturer might in delivering a lecture. Each teacher was trained specifically on each of the lessons to be delivered and on each treatment variation. Consequently, the teachers could use the scripts primarily for quick reference rather than having to read or refer to them at length. In short, the teachers were able to behave in what seemed to be a normal classroom manner, maintaining frequent eye contact with the students and using normal inflections and intonations, without seeming to be conforming to the script as closely as they actually were.

Each lesson script was written by one of five staff members of the Program on Teaching Effectiveness in accordance with an outline. All of the outlines had been written by one member of the staff to ensure consistency and continuity from one lesson to another. Each lesson script draft was then reviewed by at least two staff members. A single staff member did the final editing of all the scripts. During the training of the teachers, several useful suggestions by teachers were incorporated into the scripts.

The Students

The students participating in the experiment were sixth graders attending public schools near Stanford University. The teaching was carried out in the students' own classrooms or in adjacent rooms that, as will be indicated below, were needed to accommodate the students who were taken from their regular classrooms for the experiment. The decision to conduct the experiment in the schools themselves, rather than to bring the students into a special laboratory setting, was made after weighing the advantages of both options. One advantage gained by working in the public schools was that the students were in a more normal environment, one whose "ecological validity" was probably superior to that of a laboratory setting. The school setting also avoided the effort and cost of transporting the students from their schools or homes into the laboratory. Finally, since the experiment was conducted during the regular school year, working in the schools entailed much less interference with the students' academic schedules. On the other hand, a laboratory setting would have permitted high-fidelity audio and video recording that was impossible in the schools. Moreover, it would have permitted a greater standardization of the physical setting for the experiment. In the end, the former set of advantages was considered to outweigh the latter, and the school setting was chosen.

The school districts that agreed to permit the use of their facilities and the involvement of their students were populated primarily by middle-class families living in suburbs. The central office of the school district was approached first to obtain permission to approach the school's principal. Then the nature, purposes, and methods of the experiment were outlined to him or her. The principal in turn solicited the cooperation of the teachers whose students would participate. This recruitment process was uniformly successful; no refusals were encountered among the schools whose cooperation was sought.

As Table 2 shows, the students had a mean age of 11 years 11 months, with a range from 10 years 3 months to 13 years 5 months. There were 212 girls and 196 boys; the mean age of the girls was 11 years 10 months, and that of the boys was 12 years 0 months.

TABLE 2

Distribution of Students by Age and Sex

Age	Girls	Boys	Total
13y - 13y 5m	3	9	12
12y6m - 12y11m	13	20	33
12y - 12y 5m	54	72	126
11y6m - 11y11m	104	71	175
11y - 11y 5m	36	22	58
10y6m - 10y11m	1	1	2
10y - 10y 5m	1	1	2
Total	212	196	408
Mean Age	11y 10m	12y 0m	11y 11m
S.D. Age	5.1m	5.9m	5.6m

As Table 3 shows, the 408 students were enrolled in 20 different classes in nine elementary schools located in three school districts. Of the 20 classes, eight included both fifth- and sixth-grade students; in these classes, the fifth-grade students were eliminated from the groups taught for the purposes of the experiment. Data on the race of the students were not obtained, but the project staff considered the proportion of students

TABLE 3

Number of Students by District, School, Class, and Half-Class

District	N	School	N	Class	N	Half-Class	N
I	103	A	103	a	26	1	15
						2	11
				b	27	3	12
						4	15
				c	24	5	11
						6	13
				d	26	7	13
						8	13
II	194	B	51	e	26	9	13
						10	13
				f	25	11	12
						12	13
		C	29	g	15	13	15
				h	14	14	14
		D	30	i	14	15	14
				j	16	16	16
		E	41	k	14	17	14
		H*		l	12	18	12
		E		m	27	19	14
						20	13
		F	43	n	23	21	12
						22	11
				o	20	23	9
						24	11
III	111	G	26	p	26	25	13
						26	13
		H	40	q	28	27	13
						28	15
		I	45	r	9	29	9
		I		s	13	30	13
		I		t	23	31	12
						32	11

*School H is in District III

from minority groups (about 10 percent) to be representative of the schools in the districts involved. Information concerning race was omitted because of its irrelevance to the purposes of the experiment.

The sixth-grade students in each regular class [or combination fifth- and sixth-grade class] were divided at random into two half-classes. Each class was stratified according to the sex of the student, and then a table of random numbers was used. This procedure reduced by half the number of classes to be recruited and increased the opportunity for individual students in each class to participate. It was assumed in using half-classes that the results obtained in them could be generalized to regular-sized classes, though no information in support of this assumption was obtained. It is known, of course, that teachers often divide their classes into two or more relatively equal-sized groups for various purposes. The teacher then uses the classroom recitation strategy with one of the groups while the rest of the class engages in other activities.

The Teachers

The criteria used in selecting teachers for the experiment were sex, age, experience, and knowledge of science. Only female teachers were chosen, because the overwhelming majority of sixth-grade teachers are women. To reduce any possible influence of the teacher's age as a variable, only teachers between 25 and 40 years old were chosen. It was also stipulated that only experienced teachers, i.e., teachers who had had at least one year of full-time classroom work in upper elementary or junior high school grades, should be chosen. Each teacher was required to have permanent or provisional certification as an elementary school teacher in California.

The teacher's background in science was considered a significant criterion because the ecology curriculum had a scientific basis. Teachers with considerable training in science might tend to add material from their own backgrounds, thus changing the content of the curriculum. Accordingly, only teachers who had nonscience undergraduate majors and had not specialized in teaching elementary or junior high school science were selected. Although this criterion made it necessary to give the teachers more intensive training in ecology, the added control over the material taught to the students was considered well worth the extra effort.

As will be recalled, the design called for four teachers, each of whom was to teach using each of the eight treatment variations. This design permitted an investigation of teacher x treatment interaction that would not be possible with only one teacher. It also permitted the experiment to be carried out in a shorter time, since four classes could be conducted simultaneously. A larger number of teachers was ruled out because it would have required too much training effort.

Ten teachers were initially selected on the basis of these criteria. All were carefully trained for a two-week period, as described below. Midway through the training period, four of the teachers were chosen to serve as the actual teachers, and four to serve as alternates. These four alternates could take over in emergencies, and they were also employed as observer-coders to assess the fidelity of the treatment implementations. The two remaining teachers served as additional coders who provided data used in estimating the reliability of the four main coders and also served as alternative coders when needed.

An advertisement placed in local newspapers elicited responses from 184 experienced elementary school teachers. The respondents were asked over the phone to report their undergraduate major, the year in which they had last had full-time classroom experience, their sex and age, and the number of years of experience they had had in teaching at the elementary and junior high school levels. Two staff members independently reviewed the list and selected teachers who most closely met the criteria described above. The lists of the two staff members were compared, differences were resolved, and 17 teachers were asked to come for individual interviews. After discussing the experiment with each of the interviewees, the staff selected the 10 teachers who appeared to be most able to meet the demands of scheduling, training, and teaching.

The Training Program

Two weeks were devoted to training the teachers and coders. The first seven days were essentially the same for all 10 teachers; they all had to master the ecology curriculum; the components of structuring, soliciting, and reacting; and the coding system. After the selection of the four experimental teachers on Day 7, the training of the teachers and coders was somewhat different.

Training for Teachers

Two main techniques were used in training: the teachers viewed model videotapes illustrating the treatment variations, and they practiced the variations in microteaching sessions using the lesson plans. Eight model videotapes were made, each showing one of the first eight ecology units being taught in a different treatment variation. The tape of the first unit showed the HHH variation and lasted about 35 minutes. All other tapes were about 15 minutes long. The teachers in the model tapes were two male members of the research staff, each teaching a class of four or five upper elementary school students.

Two types of microteaching were used for training. Type A microteaching (MT) consisted of 10 to 15 minutes of practicing the treatment variations using peers as students, followed by videotape feedback and discussion with the research staff and teachers. This practice-feedback cycle was then repeated to allow the teachers to practice modifications suggested in the first feedback session. Type B microteaching consisted of just one 10- to 15-minute practice session with a videotape feedback and discussion. A second cycle was omitted because of time constraints and because the extra practice was not as crucial as it was when the teachers were originally acquiring the behavior.

Since the lesson plans were developed by the research staff prior to the training, modifications had to be made after the teachers microtaught with the lesson plans. The teachers thus became a collective editorial board, functioning to clarify and improve the lesson plans throughout the two-week training program.

The training schedule is shown in Figure 2. The first week was devoted to learning the ecology content and mastering the basic components of structuring, soliciting, and reacting. No effort was made during the first week to have the teachers incorporate high or low dimensions of the various behavior clusters. The objective was mastery of each teaching behavior within the three major composite variables of structuring, soliciting, and reacting. Mastery was achieved through group discussions and

WEEK 1

	Monday	Tuesday	Wednesday	Thursday	Friday
9:00 AM 12:00	Orientation Discussion of Content	Structuring Written Material and Model Tape (HHH) $2MT_A$ Cycles	Soliciting Written Material and Model Tape (HHH) $2MT_A$ Cycles	Lecture on Ecology Reacting Written Material and Model Tape(HHH) $2MT_A$ Cycles	Introduction to Observation System
1:00 PM 4:30	Written Materials re: Treatments Model Tape of Unit 1 as HHH HHH Lesson Plans	$3MT_A$ Cycles Discussion--"Low Structuring" Content Discussion	$3MT_A$ Cycles Discussion--"Low Soliciting" Content Discussion	$3MT_A$ Cycles Discussion--"Low Reacting" Mastery Testing of Content. Other Lesson Plans.	MT_B Practice LHH Treatment Variation

WEEK 2

	Monday	Tuesday	Wednesday	Thursday	Friday
9:00 AM 12:00	MT_B Practice HLH	MT_B Practice HLL	MT_B Practice LHL	Visit to California Exhibit at the Oakland Museum	Assignment of Teachers and Observers Visit School
1:00 PM 4:30	MT_B Practice HHL	MT_B Practice LLH	MT_B Practice LLL	Visit to California Exhibit at the Oakland Museum	Practice Treatments for First Phase of Experiment

Fig. 2. Schedule of teacher training activities.

microteaching, along with viewing model videotapes of the treatments. The second week was used to practice the various treatment combinations and the use of the system for coding teacher behavior. Modifications and interpretations of the curriculum continued throughout the two weeks.

On Day 1 the teachers read orientation materials, definitions of the teacher-behavior variables, and the student reading materials. They then viewed a model videotape showing Curriculum Unit 1 with the HHH treatment. A discussion of the three clusters of variables followed. At the end of the day, the teachers were given copies of the HHH lesson plan for Unit 1 and told to familiarize themselves with the structuring components for the microteaching on the following day.

Training on days 2-4 proceeded as follows: The teachers met as a group for the first half hour and viewed a model videotape demonstrating the high treatment for each of the three clusters of variables. They also viewed model videotapes of the first several units of the curriculum so that they could see the enactment of the lesson plans. The 10 teachers then split into two groups of five and practiced microteaching the lesson to each other, focusing on the high level of the treatment dimension being learned that day. These smaller groups were changed every day to allow all the teachers to see each other teach. Also, the research staff rotated through the various groups to familiarize themselves with all the teachers. At the end of the day, the teachers reconvened in a large group, discussed the treatment dimension that they had learned that day, and received the lesson plan for the next day. By the end of the week all the teachers had practiced the high level of each of the three clusters, using the lesson plans for the first three units.

During the first few days of practice sessions, it became clear that the teachers needed more background in ecology. On the fourth day a staff member lectured on the nine ecology lessons, providing more detailed information on the concepts in them. In addition, the teachers were assigned extra readings on ecology from several books (Andrews, 1974; Bakker, 1972; Kormondy, 1969; Smith, 1959).

Beginning on the afternoon of the fifth day, the teachers practiced the remaining seven treatment variations using the remaining curriculum lessons.

On Day 7 the four experimental teachers were selected by the research staff on the basis of their knowledge of the curriculum and proficiency at implementing the treatment variations. All four of the experimental teachers had to be comfortable and familiar with the material. They had to be flexible enough to employ the various combinations of the three behavior dimensions in a way that resembled regular classroom behavior.

On the ninth day, after the treatment variations and lesson plans had been practiced, all the teachers visited the California Exhibit at the Oakland (California) Museum. The exhibit dramatically displays the topography, the flora, and the fauna of the various California ecosystems. Since many of the teachers were unfamiliar with some of the facts and concepts covered in the curriculum, this trip proved to be highly instructive.

The trainees' mastery of the ecology curriculum was assessed by two tests consisting of multiple-choice and essay items. The first test covered Units 1-3, and the second test covered Units 4-6. All trainees except two scored 100 percent on the first test. The scores on the second test were not as high, but nonetheless reflected mastery of the content by all the trainees.

On the morning of the last day, all participants went to the school in which the first phase of the experiment was to take place. The teachers met their students and familiarized themselves with the logistics of the first two weeks of the experiment. That afternoon, the four experimental teachers practiced the lesson plan for the treatment variations they would teach the following Monday.

During the first two weeks of the study, the teachers taught in the morning and practiced the next day's lesson in the afternoon. There was a two-week hiatus between the first and second phases of the study. The teachers returned the Friday before the second phase and reviewed the lesson plans and treatment variations for this phase.

Training for Coding

Beginning on Day 5 all teachers practiced with the observation system. The teachers first practiced by coding one of the model videotapes. Then they took turns coding during the Type B microteaching cycles. Two teachers in each of the five-member practice groups coded, while one taught and two acted as students. The playback of the videotape then provided feedback to the coders as well as the teachers. During the playback the two coders compared their observations with the videotape and reconciled their differences with the trainer. All teachers served in turn in the teacher, student, and coder roles. After the selection of the four experimental teachers on the seventh day, the six coders spent the rest of their training time practicing coding the microteaching behaviors of the experimental teachers. Small modifications were made in the observation system during training procedures.

Instruments

The instruments used in this experiment fall into three categories: pretests, posttests, and retention tests. All pretests were administered approximately one week prior to the teaching; the posttests were administered on the day following the nine-lesson curriculum; and the retention tests were administered approximately 20 days following the posttests.

Pretests

Eight major pretests were administered to the students. These measures and the scores derived from them are described below.

Vocabulary test. It is important that at least one pretest in studies of this sort be a standard measure of scholastic aptitude, one that is common to many other investigations. Such a measure is an aid in interpreting the findings of the current study and in relating them to the findings of prior research. For our experiment levels D-F of Form 1 of the vocabulary subtest of the Cognitive Abilities Test (Thorndike & Hagen, 1971) were chosen as a measure of scholastic aptitude. The set of 35 items is described as appropriate for students in grades 6 to 9 in average schools, and grades 5 to 8 in above-average schools. It was assumed that a test designed for this range of grade levels would be the most appropriate for the sample used in this research and would decrease the probability of a ceiling effect. The time allotment of seven minutes for the usual scale length of 25 items as indicated in the test manual was increased to nine minutes to accommodate the additional 10 items.

The number of vocabulary items answered correctly served as the measure of scholastic aptitude for each student.

Memory tests. Four different kinds of memory tests were developed for this study to help detect aptitude-treatment interactions.

The word list test was a list of 24 randomly ordered nonproper nouns. The nouns could be categorized into four categories of six members each, e.g., "fruits," containing the members banana, grape, pear, pineapple, peach, and melon. Students were given free-recall instructions for the words on the list, having two minutes to study the 24 items and two minutes to recall all the nouns they could. Two scores were derived from this protocol. The total number of words recalled correctly served as an index of semantic memory for units, after Guilford (1967). This score was labeled the word list item score. A score representing the student's memory style for category organization was derived as follows. Since the nouns could be categorized into four sets of six members, it was inferred that the student used category units as cues for recall (e.g., Mandler, 1967) if (a) at least three nouns per category, one of which could be a category intrusion, were recalled; and (b) these three words were adjacent in the student's protocol list.

The word groups test also consisted of a randomly ordered list of 24 nonproper nouns that could be grouped into four categories of six words each. In contrast to the word list test, however, students were explicitly asked to organize the words into groups as they recalled them. Instructions for the test provided students with a model of categorical organization and the format for their recall protocol. Students were allowed two minutes to study the word list and two minutes to write all the nouns they could remember. At the end of the study period, instructions for recall again stressed that the students should group the nouns they remembered into categories. The number of nouns recalled was labeled the word groups item score, and the number of categories used for recall was termed the word groups category score.

The third memory test, the word pairs test, was designed to measure students' associative memory ability as enhanced by their use of mnemonic coding strategies. The test presented 15 pairs of nouns. The students were given instructions concerning the use of sentence coding and imagery coding as possible aids to recalling the paired associate of the first noun of a pair. Students were provided with a one-minute period to try these processes before the actual test, so that they would not waste study time in choosing a strategy for learning. After the two-minute study trial, two minutes were allowed for recall. During this period, the students were to provide the second word for each previously studied pair on presentation of the first word. The first words were randomly rearranged in the recall list to prevent the students from using serial association. The number of correctly recalled paired associates served as the word pairs item score.

After the two-minute recall period, students were asked to rate on a four-point scale how much they used rote memory, sentence mnemonics, imaginal mnemonics, or some other learning strategy, if any, for this task. If they reported using another strategy to any degree, they were asked to describe that strategy briefly in their own words.

To measure an ability different from mnemonic paired-associate learning ability, students were given the object-number test, part 1, from the French Kit of Reference Tests (French, Ekstrom, & Price, 1963). This test is regarded as a measure of "pure" associative memory ability. It presents 15 noun-number paired associates to be studied for three minutes and allows two minutes for recall of the number associated with each noun. The noun cues were randomly rearranged on the recall list to prevent serial association. The number of correctly recalled number associates served as the object-number item score.

True-false knowledge of ecology. School instruction almost invariably builds new learning on the foundation of previously acquired information. Indeed, some educators have identified this phenomenon as an important and valued characteristic of education (e.g., Bruner, 1966). Since ecology is a currently popular topic and since portions of the information presented in the ecology curriculum used for this study are studied in elementary school science courses, an estimate of students' prior knowledge about ecology was judged to be potentially valuable in assessing students' learning. Also, it could be conjectured that prior knowledge would have a different influence on learning under different teaching treatments. The true-false knowledge of ecology instrument (see Appendix C) was designed to measure students' prior knowledge of concepts taught in the ecology curriculum. Students were presented with 20 statements that could be classified as either true or false. To improve the reliability of the true-false item format, students also were given the option of indicating that they were uncertain whether a statement was true or false by marking a question mark (rather than t for true or f for false). The instructions explicitly and forcefully requested students not to choose the true or false option unless they were almost certain that the item was true or false. Items marked "question mark" were scored as incorrect and the total number of items correctly marked true or false served as the prior-knowledge score.

Attitude toward ecology. It seems reasonable to hypothesize that student interest in a subject area partially determines achievement. It is also possible that student interest in a subject area will be increased or decreased by the way the curricular material is taught. Thus student interest in ecology may interact with the style of teaching, differentially affecting the outcomes of instruction in both the cognitive and affective domains. A 12-item measure of student attitude toward ecology (see Appendix C) was accordingly administered as a pretest. Each item requested the students to indicate their level of agreement with statements such as "I'd like to learn about the science of ecology" on a five-point scale ranging from "strongly agree" to "strongly disagree." Items phrased as expressing a lack of interest were reversed in scoring so that a high score reflected positive interest in the study of ecology.

Student preference for teaching style. Students often express pleasure or displeasure with the procedures and styles of their teachers. These expressions often are global, such as "The lesson was disorganized." A theory offered by Hunt (1971; see also Hunt & Sullivan, 1974) suggests that matching student learning style and the learning environment, a major portion of which is the teacher's style, will facilitate achievement. In contrast, mismatching of this sort will decrease achievement. Hence, an instrument for measuring student preference for teaching styles (the teaching attribute scale, shown in Appendix C) was developed and administered. For each of its 15 items, such as "The teacher ties together ideas during the lesson," students were asked to estimate how much they would learn if a teacher acted in accordance with the statement. The students responded on a five-point scale ranging from "not at all" to "a lot more than usual."

Each item on this instrument corresponded to one of the components of the three composite independent variables--structuring, soliciting, and reacting. Five items pertained to the components of structuring, three to the components of soliciting, and seven to the components of reacting. Thus item scores reflected student preference for specific teacher acts in terms of the student's estimate of how that action would influence learning. Separate scores for structuring, soliciting, and reacting thus reflected student preference for the three composite dimensions of teaching manipulated as independent variables.

Posttests

One primary goal of teaching is to foster student acquisition and understanding of the information presented during instruction. Since in schools this kind of achievement is usually assessed by multiple-choice and essay tests, both types of achievement measures were used in this study. In addition, it is important to assess whether teaching promotes positive student attitudes toward the subject matter. Therefore, an attitude instrument was also administered as a posttest. Finally, it was judged valuable to have student estimates of the characteristics of instruction. Thus several instruments were designed to obtain information about features of the teaching and characteristics of the teachers which were prominent during instruction.

The multiple-choice test. The multiple-choice test (see Appendix C) was composed of 36 four-alternative items. The items were selected from a pool of items classified according to three dimensions: (a) the source of instruction on the item: the text read by the student or the teacher; (b) the lesson in which the information on the item was taught; and (c) the level of the cognitive process, lower-order or higher-order, required to answer the item. One item from each cell of this 2 x 9 x 2 matrix was selected, so that no two items tested identical curricular information. All items were reviewed by four judges for clarity and content validity. Marginal totals from this matrix specified plausible multiple-choice subscales, e.g., high-order and low-order question subscales, subscales pertaining to each lesson, text-as-source and teacher-as-source subscales. The items composing these subscales are listed in Appendix C. The number of items answered correctly served as the total or subscale score for these measures.

The essay test. The essay test of achievement (see Appendix C) consisted of three items, each intended to elicit a response of approximately 75 words. One item was drawn from the material examined in lessons 1 through 5, and one from lessons 6 through 9; the third item spanned the content of all nine lessons. The three items required the student to apply concepts and principles learned during instruction in explaining the way ecology defines one of its classificatory principles (Item 1) and in new situations (Items 2 and 3).

For each essay test item, an ideal answer was written, one that identified necessary concepts and relations. If these concepts and relations were accurately stated and sufficiently elaborated, a score of 2 was given. If they were accurately stated without elaboration, a score of 1 was given. If they were incorrectly stated or absent, a score of 0 was given. The ideal answer for Item 1 contained seven statements, so that the maximum score was 14. Items 2 and 3 had maximum scores of 6 and 12, respectively. Thus, the total possible score on the essay test was 32. The scoring criteria for each item are presented in Appendix C. Two judges independently scored each item and then resolved any differences between their item scores; the resulting item scores were summed to produce a total essay score for each student.

Attitude toward ecology. An important outcome of instruction is the students' attitude toward the subject matter. Thus students again responded to the attitude toward ecology inventory measure after instruction.

The treatment perception scale. Student perceptions of the teaching methods were obtained by readministering the items of the teaching attribute scale with new directions. In this new form the instrument was called the treatment perception scale. As described above, this instrument elicited student perceptions regarding each of the components of the three composite independent variables--structuring, soliciting, and reacting. The new instructions for the posttest version of this instrument asked students to describe the extent to which their ecology teacher acted in accordance with each statement. Again, separate scores for structuring, soliciting, and reacting were derived.

The student perception of teacher characteristics scale. A second measure of students' perceptions of the characteristics of their ecology teacher was obtained as a posttest. This was labeled for students the teacher characteristics scale (see Appendix C), but it would be more accurately labeled a "student perception of teacher characteristics" scale. Much research on teacher effectiveness has found significant correlations between certain rated characteristics of teacher behavior and student achievement (Rosenshine, 1971). It may be argued that student ratings of teacher behavior will be more closely associated with achievement than are more objectively observed behaviors because the effect of teacher behaviors and characteristics must be mediated by students' perceptions of them. Thus students were asked to rate their ecology teacher on 12 items, such as "[the teacher] presents ideas so I can understand them," by marking how often their ecology teacher acted this way on a five-point scale extending from "almost never" to "almost always." The 12 items could be grouped into six mutually exclusive two-item subscales labeled enthusiasm, knowledge of subject matter, warmth, management, organization, and clarity.

Since the items on the student perception of teacher characteristics scale and the treatment perception scale had the same response formats and similar content, they were numbered sequentially in the student test booklet and administered as a single instrument.

Retention Tests

Schooling is intended to affect students both immediately and at later points in their lives. Thus it is important to determine the durability of students' achievement and attitudes. To measure retention of these effects, several instruments were readministered to the students approximately 20 days after the posttests. Two major types of retention measures were administered: measures of curriculum-relevant learning and a measure of interest in the curriculum topic. The former included three distinct measures, namely, the same multiple-choice and essay tests that had been used as a posttest. The measure of interest in ecology was the same as the one used as a pretest and a posttest.

The Observation Instrument

An observation instrument was developed to measure the fidelity with which the teaching behaviors were manipulated in this study. The instrument called for the observer-coder to check which one or more categories of events occurred during each 10-second interval of the observation period.

Since the purpose of this system was to measure the fidelity of treatment implementation, the system was designed to include only those behaviors manipulated in the experiment. Thus the categories of events checked were the components, described above, of teacher structuring, teacher soliciting, student talk or responding, and teacher reacting. In addition, two other categories were included: teacher presenting information and unclassifiable. Teacher presenting information was to be used when the teacher was lecturing or giving new information, i.e., information not previously presented. According to this definition, teacher structuring and teacher presenting information were independent dimensions. Unclassifiable included simultaneous student talk, disruptive remarks, and other events that did not fit into any other category.

The observation system is provided in Appendix D. The behaviors observed are listed on the left-hand and right-hand sides of the form for ease in coding. Each column of the observation form was to be used for one of the 24 10-second intervals, or four minutes of classroom interaction, for which a given page was usable. During each 10-second interval, the coder checked the one or more teaching behaviors that occurred. The form also had places for the identification of the teacher, the coder, the class, the session, the date, the starting and ending times of the session, and the page number. At the end of each session, the coder totaled the number of checks made for each teaching behavior during the session.

After the training of the coders was completed, data were collected on the generalizability of the observation instrument using the procedure outlined by Cronbach, Gleser, Nanda, and Rajaratnam (1972). In a microteaching situation three teachers, each using a different one of the eight treatment variations, taught a lesson lasting 10 to 15 minutes on the same unit to their teaching peers. Six coders recorded the interaction for the three sessions. The facets for the generalizability study design were treatments and coders. In this study teachers were confounded with treatments, so that the variance due to teachers could not be separated from the variance due to treatment. Thus the "true score" variance was the variance due to teachers (treatments), and the "observed score" variance equaled the sum of the true score variance and the variance component for the teacher (treatment) by coder interaction. The generalizability coefficient equals the true score variance divided by the observed score variance.

Table 4 presents the variance components and the generalizability coefficient for each observation category. For example, the generalizability coefficient for the structuring total score equals .98. This value indicates the generalizability coefficient that would be predicted for only one coder. As can be seen, most of the generalizability coefficients were greater than .75, indicating that the generalizability of the observation instrument was adequate for the purposes of this experiment. For 18 of the 28 categories, the variance due to coders was zero, suggesting that the agreement among coders was very high for these categories.

The categories that represent the levels of the treatment variations are structuring total, lower-order questioning, higher-order questioning, low reacting total, and high-reacting total. The generalizability coefficients of structuring, lower-order questioning, and high reacting were .98, .89, and .90, respectively. The generalizability coefficients of higher-order questioning (.36) and low reacting (.27) were much lower. The reason for these low generalizability coefficients might be the infrequent occurrence of these behaviors, which resulted in very little "true score" variance. The behaviors occurred infrequently because the lessons taught for the generalizability study lasted 10 to 15 minutes instead of the usual 35 minutes.

TABLE 4

Variance Components and Generalizability Coefficients for the Observation Categories

Observation Category	σ^2_T	σ^2_C	σ^2_{TC}	Observed-Score Variance $(\sigma^2_T + \sigma^2_{TC})$	Generalizability Coefficient $(\sigma^2_T/\sigma^2_T + \sigma^2_{TC})$
	Variance Components				
Structuring Total	142.878	2.011	2.289	145.167	.98
Reviewing	4.444	0.000	0.889	5.333	.83
Stating Objectives	4.889	0.000	0.056	4.945	.99
Outlining	29.978	0.000	0.189	30.167	.99
Signaling Transitions	3.889	0.944	0.772	4.611	.84
Emphasizing Important Points	1.122	0.200	0.656	1.778	.63
Summarizing	0.000	0.000	0.000	0.000	—[a]
Teacher Presenting Information	156.8[illegible]	0.000[b]	5.366	162.166	.97
Soliciting Total	57.578	1.589	4.089	61.667	.93
Lower-Order Questioning	43.122	0.656	5.322	48.444	.89
Higher-Order Questioning	1.733	2.067	3.100	4.833	.36
Responding Total	44.367	0.000[b]	12.855	57.222	.78
Student Responses	77.467	0.000[b]	10.589	88.056	.88
Student Questions	3.778	0.000	0.222	4.000	.94
Student Comments	1.978	0.000[b]	3.522	5.500	.36
Low Reacting Total	1.045	0.000[b]	2.789	3.834	.27
Neutral Feedback	1.556	0.000	1.389	2.945	.53
"No"	0.000	0.000	0.000	0.000	—[a]
Probing	0.033	0.000	0.189	0.222	.15
High Reacting Total	64.767	0.000[b]	7.455	72.222	.90
Praise	28.378	0.089	0.455	28.833	.98
"No" + Reason	0.033	0.000[b]	0.967	1.000	.03
Prompting	6.522	1.300	4.589	11.111	.59
Writing Student Ideas	0.000	0.000	0.000	0.000	—[a]
Redirecting	0.744	0.000[b]	0.200	0.944	.79
Giving Correct Answer	1.167	0.089	1.389	2.556	.46
Unclassifiable	1.822	0.000	1.567	3.389	.54
Total Observations	79.878	12.067	35.232	115.110	.67

[a] The coders were in complete agreement that this behavior did not occur. However, because there was no variance among teachers and raters on the behavior, the generalizability coefficient cannot be estimated.

[b] Negative variance component has been set to zero (Cronbach et al., 1972, p. 57).

Because the conditions in the generalizability study were not exactly like those in the experiment, the generalizability coefficients should be regarded as estimates of the dependability of behavioral observations in the experiment. The generalizability of the coding of 40 minutes of teaching behavior to about 13 sixth-grade students in a classroom situation might be appreciably different from the generalizability of the coding of 10 minutes of teaching behavior to about 5 adult students in a laboratory situation. The intercoder reliability of the observation data collected during the actual experiment is presented in Chapter III. (The data obtained during the experiment permitted an estimate only of intercoder reliability rather than the generalizability.)

Anecdotal Classroom Observations

In addition to the behavioral observations made by the coders using the observation instrument, anecdotal classroom observations were made daily by the researchers. The latter were very familiar with the intended treatments because they had planned the experiment and trained the teachers. Each researcher had a copy of the day's lesson plan, which prescribed the treatment variation and the ecology material for that day. Using the lesson plan, the researcher followed along as the teacher taught the lesson. As the lesson progressed, the researcher made notes in the appropriate places in the lesson plan. The following types of events were noted:

1. Deviations from the intended treatment variation (e.g., teacher praises in the low-reacting treatment).
2. Deviations from the intended content to be taught (e.g., student digresses from the topic, teacher mentions new material).
3. Incorrect statements about ecology (e.g., teacher accepts incorrect student answer, teacher makes incorrect statement about ecology).
4. Student disruptions and other disruptions.
5. Pace of the lesson.
6. Impressionistic evidence about the students.
7. Impressionistic evidence on the quality of the teaching.
8. Presence or absence of the regular classroom teacher.
9. Distribution of questions to students.

10. Student attendance.
11. Length of the lesson.
12. Functioning of audio-recording equipment.
13. Functioning of the coders using the observation instrument.

Recording for Secondary Analyses

All teaching sessions were audiotaped to obtain records for possible use in secondary analyses. In addition, each class was videotaped either during Lesson 8 or Lesson 9.

The audiotaping system (Fig. 3) consisted of a stereo cassette recorder and two microphones. The first microphone was worn by the teacher, and the second microphone was mounted on a stand to record student voices. Signals from the two microphones were fed into the two separate channels of the stereo recorder so that the sound of student voices would not override the sound of the teacher's voice and vice versa.

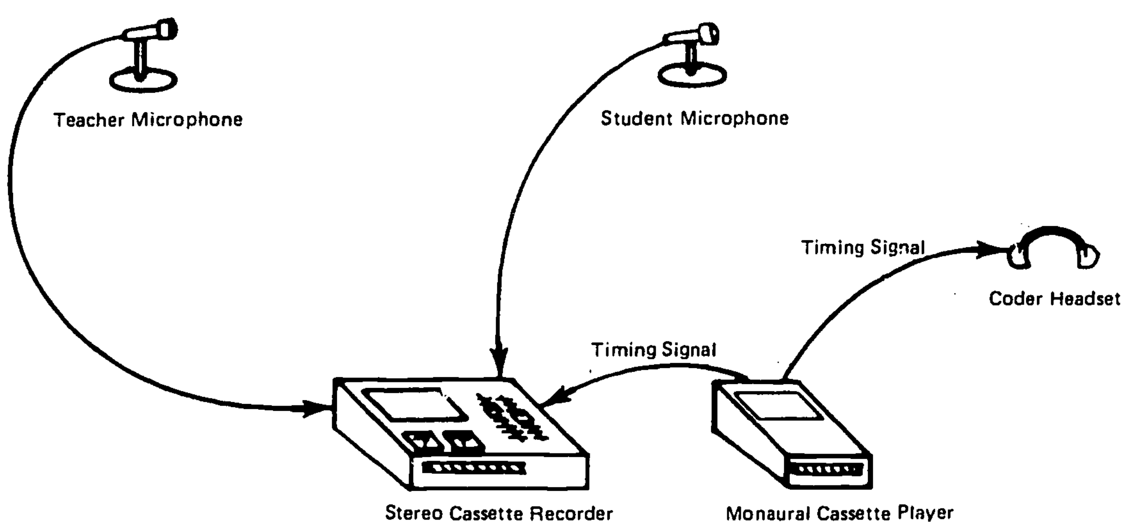

Fig. 3. The audiotape recording system.

At the suggestion of Ned A. Flanders, the audio signal used to pace the coders of the classroom interaction (a spoken numeral given at 10-second intervals) was transmitted both to the earpiece worn by the coder and to the teacher-input channel of the stereo audiotape recorder. The complete stereo audiotape of each teaching session, then, consisted of the students' voices on the first track and the teacher's voice on the second track, with the timing signal superimposed on the second track.

Procedures

Random Assignment of Students and Teachers to Treatments

Twelve whole classes of sixth-grade students were stratified on sex, and each class was randomly divided into two half-classes. Eight other classes consisted of fifth- and sixth-grade students. The fifth-grade students were eliminated from the study, leaving eight half-classes of sixth-grade students. Each of these eight half-classes was matched with another half-class in the same school, creating four matched pairs. Within each two-week time block, half-classes were randomly assigned to treatment variations. The random assignment of half-classes to treatments was done in such a way that, within each whole class or matched pair of classes, the treatment variations differed only on structuring. For example, one half of the class received the high structuring-high soliciting-high reacting treatment (see Fig. 1). This within-class structuring contrast was used to increase the precision of the test for the structuring effect.

The four teachers were randomly assigned to the sequence in which they would teach the eight treatment variations. This was done because no teacher taught the same treatment twice during the experiment. Thus, Teacher 1 taught the LHH and HLL treatments during the first time block; the HHH and LLL treatments during the second time block; and the LHL, LLH, HHL, and HLH treatments during the third time block. The assignment of teachers to treatment sequences is shown in Figure 1.

Assignment of Coders

Coders were assigned to remain with the same teacher for the entire two-week time block. Coders were then assigned to a new teacher for the next two-week time block. During each two-week period, two coders served as "reliability coders." Reliability coders moved to a different class each day so that each primary coder had a reliability coder coding with her at least once per day.

Pretesting

The students were pretested during the week before the two-week teaching period. The tests were given in their regular classrooms during the normal school day by the research staff with the regular classroom teacher present. Since the pretesting experience constituted the students' first contact with the experiment, the staff member took a few minutes to describe the study to the students before beginning the pretesting. The staff member also explained the purpose of the testing session to the students.

Each student was given a booklet containing all the pretests described above. The single booklet saved time that might otherwise have been taken up in passing out and collecting individual tests. The staff member read aloud the directions for each test and asked the students if there were any questions. Further explanations of the directions were given as necessary. Most of the tests were timed, and the entire pretesting session took approximately 50 to 60 minutes. While the students were taking the tests, the staff member monitored their behavior.

One or two follow-up testing sessions, at which the same procedures were followed, were held for absentees.

A Typical Teaching Day

The teaching day began at 8:30 a.m., when the teachers, coders, and research staff met at the Stanford Center for Research and Development in Teaching. The staff then drove the teachers and coders to the appropriate teaching site, arriving at about 8:45 a.m. Accompanied by a staff member and one or two coders, each teacher proceeded to the room in which she would teach. Arriving about ten minutes before the lesson was to begin, the staff member and the coder(s) set up the audio-recording equipment, while the teacher arranged the students' seats, took attendance, and talked informally with her students.

The teacher began the lesson at the appointed time by passing out the ecology booklet for the day's lesson. (Appendix A contains copies of all nine booklets.) The students were given five minutes to read the ecology material. At the end of five minutes, the teacher collected the booklets whether the students had finished reading or not; most students were able to finish. After the booklets were collected, the teacher began the recitation according to the lesson plan. (Appendix B contains master lesson plans.) The lesson typically lasted 30 to 40 minutes. During the lesson the regular classroom teacher sometimes remained in the room, sitting quietly in the background. As requested, the regular classroom teacher never interrupted the lesson or interfered with student behavior problems, so that the experimental teacher was always in charge of the class. When the lesson was completed, the staff member and the coder packed up the audio-recording equipment and returned the chairs in the room to their normal places. The group then proceeded to the next school where the same procedure was carried out, except that the experimental teacher used a different treatment variation. The procedure for a typical teaching day was repeated for nine days.

Posttesting

Posttesting was carried out on the tenth day by the research staff without the experimental teacher. Students were tested in their regular classrooms during the normal school day. The regular classroom teacher was usually present during posttesting.

On the tenth day after teaching began, students were given a booklet containing the posttests already described. The staff member read aloud the directions for each test to the students and answered student questions on the directions. If a student had a question on a particular test item, the staff member responded by paraphrasing the wording of the test item. The wording of the essay items proved to be particularly difficult for some students to understand. Thus the tester usually reworded each essay item and explained it to the whole class. During the testing, which lasted approximately 45 minutes, the staff member monitored the class.

Three weeks after the posttesting, students were given the retention tests described above. The retention testing procedure was the same as the posttesting procedure. The retention testing session took about 50 minutes.

Anomalous Occurrences

In general, the teaching and testing proceeded as planned, and few anomalies occurred. Most of these were minor and usually were the result of practical limitations. For example, there were often not enough normal classrooms in which the teaching could take place. Therefore, some of the teaching sessions were held in the library, the art studio, or the multipurpose room. Sometimes the class had to be held in the library one day and the multipurpose room the next day. It is possible that these different settings affected student attitude and student achievement. Similarly, the time of the lesson sometimes differed from day to day, particularly during the third time block. Time changes were usually the result of conflicts with special activities that had been planned by the school or the regular classroom teacher. One such activity was a field trip that had been planned for several weeks by one school. Because of this field trip, the students were asked to come to school early that day to have the ecology lesson before leaving on the trip. As a result, many students straggled into the ecology lesson late or did not appear. In addition, the students' excitement about the upcoming field trip probably affected their performance and attention during the ecology lesson.

Some other minor anomalies should be noted. There was not always a researcher in the room with the coder and the experimental teacher during the lesson. Sometimes there was a delay in starting the lesson because of malfunctioning audio-recording equipment. Finally, some of the students were absent on the tenth day and were tested later. This delay may have affected their achievement.

One major anomaly did occur during the last week of the experiment. Teacher 1 arrived late one day, and her class (half-class 28) was taught by her coder. According to the researcher who was present, the coder implemented the treatment faithfully, and the ecology material was well taught. This was the only substitution necessary during the experiment.

Chapter III. RESULTS OF THE EXPERIMENT

In this chapter, we describe our data analysis procedures and then the results of the experiment. We first present information on the reliability of the premeasures, the postmeasures, the retention measures, and the behavioral observations. Second, we present information on the fidelity with which the treatments were carried out; these data show, in terms of frequencies of various kinds of behavior, the degree to which the various treatments were actually applied in the classroom. Third, we discuss factors affecting the interpretation of the data. Fourth, we present the various descriptive statistics on the pretest variables to show the ways in which these scores did or did not vary as a function of district, school, class, half-class, treatment, and teacher. The means, standard deviations, and intercorrelations among the pretest and posttest variables will also be provided. Fifth, the overall changes in student achievement and attitude from pretest to posttest and retention are considered, and the significance of the changes in means are reported.

Finally, we turn to the effects of the treatments and the teachers--effects that indicate the degree to which the teacher behaviors manipulated in this experiment had an effect on the students' and half-classes' achievement and attitudes, both on the day after instruction ended and three weeks later. A subsequent experiment, performed to determine whether any of the eight kinds of teaching had any advantage over merely reading the text materials, is then described. The consideration of the treatment and teacher effects is supplemented by a summary of an investigation of aptitude-treatment interactions. Here we examine the degree to which the effects of the treatments on the dependent variables were a function of the students' "aptitudes," as measured by the various pretests described in Chapter II, and various other characteristics of the student. The students' perceptions of the treatments, as measured by the treatment perception scale, provide another approach to the estimation of the efficacy of the manipulated variations in teacher behavior. Accordingly, a path analysis of these data, in relation to the intended behaviors of the teachers and to the students' achievement and attitude scores, is reported.

Data Analysis Procedures

The student data consisted of responses to pretests, posttests, and retention tests. Each of these sets of tests was administered in the form of a single booklet. All student responses (except for those to several of the memory tests) were coded by trained clerks in raw form, i.e., directly from the booklets without transformation or scoring. A computer program was written to transform these raw data into scored data from which a master data file was created. The master data file contained scale and subscale scores for each student in the experiment.

At each point in the data preparation sequence, checks on the accuracy of the procedure were applied. The accuracy of the coding of the raw data was checked by choosing at random the pretest, posttest, and retention test booklets of five students. These booklets were then coded by each of the teams of clerks. Examination of these protocols showed that the percentage of miscodes was less than 0.8 percent of the total number of items coded.

The two computer programs for transforming the raw data into scored data and then into the master data file were checked for several randomly chosen complete sets of student data. Hand-scored results on these sets were compared with those of the computer program. After an initial revision, the data generated by the computer corresponded perfectly with those obtained by hand scoring. A similar procedure was used to code and check the observation data on the teachers' behaviors. In addition, several computer programs were used to produce descriptive statistics such as the maximum and minimum scores, the range, the number of cases without missing data, and so on, in both the student data and the observation data. It seems reasonable to estimate the accuracy of both sets of data as equal to at least 99 percent.

Usually as the result of absences, some students did not take one or another of the tests. For many of the statistical procedures, only students with complete data could be included. The selection of such students did not bias the experimental sample substantially, since comparisons of the reduced data sets with the complete set of students indicated no statistically significant differences. Thus, the disadvantages of having an incomplete data set do not appear to have introduced a bias into the experimental sample.

The Statistical Package for the Social Sciences (Nie et al., 1975) and the Biomedical Computer Programs (Dixon, ed., 1973) were used to perform the statistical analyses. In addition, two computer programs of the Stanford Center for Research and Development in Teaching were employed to perform item analyses and tests of homogeneity of regression, respectively.

Reliability of the Instruments

The Student Measures

As shown in Table 5, all but one of the various pretests, posttests, and retention tests had adequate reliability coefficients. The exception was the teacher-only-as-source, lower-order subscale, which had a reliability of only .33 on the posttest and .43 on the retention test. Reliability was estimated by coefficient alpha for the aptitude tests that were regarded as measuring a homogeneous set of abilities without any apriori distinctions built into the content of the test. Thus, the reliability of the vocabulary pretest was .81, and that of the attitude-toward-ecology pretest was .83. Where the content of the test did reflect certain logical distinctions, such as that between lower-order and higher-order questions in the multiple-choice achievement test on ecology, corrected split-half coefficients of reliability were obtained. These split-half coefficients were computed by correlating the score for the odd-numbered items with the score for the even-numbered items and applying the Spearman-Brown formula. The coefficients in Table 5 have been labeled to indicate which of these two kinds of coefficients was obtained. As Table 5 indicates, these coefficients ranged from .33 to .89, and all but two of the coefficients were higher than .50. With the possible exception of the "teacher-only-as-source: lower order" subscale, it appears that the various instruments were adequate in internal consistency.

The correlation between students' scores on the posttest and scores on the retention test, given three weeks later, are presented in Table 28. Although no treatments intervened between the posttest and the retention test, the teaching variations might conceivably have differentially affected changes in students' scores from the immediate posttest to the retention test. Thus, the test-retest correlation should be considered a lower bound of the reliability of each test.

TABLE 5

Reliability of the Instruments

Instrument	N	No. of Items	Mean	SD	Reliability
Pretests					
Vocabulary	386	35	21.23	5.50	.81[a]
Attitude-toward-ecology	386	12	44.26	7.52	.83[a]
True-false-? knowledge of ecology	386	20	7.55	2.68	.50[b]
Posttests					
Multiple-choice achievement total	386	36	20.44	5.82	.80[b]
Text-and-teacher-as-source: lower-order subscale	386	9	5.37	1.78	.52[b]
Text-and-teacher-as-source: higher-order subscale	386	9	5.42	2.00	.57[b]
Teacher-only-as-source: lower-order subscale	386	9	4.70	1.68	.33[b]
Teacher-only-as-source: higher-order subscale	386	9	4.96	2.00	.58[b]
Attitude-toward-ecology	385	12	42.73	8.18	.86[a]
Essay test on ecology	385	3	1.76[c]	1.74	--
Retention tests					
Multiple-choice retention total	386	36	18.90	6.52	.85[b]
Text-and-teacher-as-source: lower-order subscale	386	9	4.79	1.89	.51[b]
Text-and-teacher-as-source: higher order subscale	386	9	5.17	2.14	.61[b]
Teacher-only-as-source: lower-order subscale	386	9	4.14	1.81	.43[b]
Teacher-only-as-source: higher-order subscale	386	9	4.80	2.12	.65[b]
Attitude-toward-ecology	384	12	40.52	9.00	.89[a]
Essay test on ecology	386	3	1.02[c]	1.60	--
True-false-? knowledge of ecology	384	20	11.43	3.07	.62[b]

[a]Coefficient alpha
[b]Corrected split-half estimate
[c]The total-points-possible on the three-item essay test was 32, as indicated on page 44; hence, the means of the obtained scores were very low.

The frequency distributions of the various measures, except the essay test, were approximately unimodal and symmetrical, with no marked skewness. Scores on the essay test were extremely skewed, with most scores piling up at the low end of the distribution; for this reason, as described below, they were subjected to a logarithmic transformation.

The Observation Data

Since the observations of the teachers' behavior were used to determine the fidelity with which the teachers carried out the intended treatment variations, it was important that these observations be reliable. As already noted, each coder was joined on various occasions by a second coder who had been chosen and trained in the same way. The degree to which the two coders agreed in their observations was estimated by computing the correlation between their observations of a particular behavior for the occasions on which the two coders coded the same teaching session. Each coder was paired with every other coder an a[illegible] of 10 times during the experiment. (Three possible pairings of coders never occurred because the two coders who served as reliability coders during each time block were never paired with one another.)

Tables 6 through 9 present intercoder correlation matrices for the observation variables. Each correlation in the matrix is based on the number (N) of teaching sessions in which two particular coders were paired. The intercoder correlations for the number of check marks made during the 10-second coding intervals to indicate occurrence of an aspect of the structuring variable are shown in Table 6. The correlations ranged from .95 to .99 with an average of .99. (To obtain an average intercoder correlation for each variable, the intercoder correlations were first transformed to Fisher's z-transformations. The z-transformations were then averaged for each observation variable, and the average z-transformation was transformed back into a correlation coefficient.) These data indicate that the coders clearly agreed when structuring did or did not occur during a teaching session.

TABLE 6

Intercoder Reliability of Amount of Time Spent in Structuring: Correlations Between Coders' Observations of the Same Teaching Sessions

	Coders					
	C_1	C_2	C_3	C_4	C_5	C_6
C_1		.99 (N=12)**	.99 (N=10)	.99 (N=12)	.99 (N=13)	—*
C_2			.99 (N=9)	—*	.99 (N=8)	.96 (N=13)
C_3				.98 (N=8)	—*	.97 (N=10)
C_4					.99 (N=11)	.99 (N=10)
C_5						.95 (N=11)

*These coders served as reliability coders during the same time block and were never paired with each other.

**Numbers in parentheses indicate the number of teaching sessions in which the coders were paired.

Table 7 shows the intercoder correlations for higher-order questions and lower-order questions, respectively. The results for higher-order questions vary widely, with intercoder correlations ranging from .21 to .99 and averaging .84. The intercoder correlations for lower-order questions were generally lower, averaging .79. The reliability of the coders' observations of reacting behaviors can be seen in Table 8. The average intercoder correlations were .98 and .96 for high reacting and low reacting, respectively.

TABLE 7

Intercoder Reliability of Amount of Time Spent on Higher-Order Questions (Correlations above Diagonal) and Lower-Order Questions (Correlations below Diagonal): Correlations Between Coders' Observations of the Same Teaching Sessions

	Coders					
	C_1	C_2	C_3	C_4	C_5	C_6
C_1		.83 (N=12)**	.84 (N=10)	.94 (N=12)	.75 (N=13)	—*
C_2	.96 (N=12)		.99 (N=9)	—*	.45 (N=8)	.79 (N=13)
C_3	.56 (N=10)	.68 (N=9)		.21 (N=8)	—*	.77 (N=10)
C_4	.81 (N=12)	—*	.74 (N=8)		.87 (N=11)	.52 (N=10)
C_5	.77 (N=13)	.63 (N=8)	—*	.86 (N=11)		.93 (N=11)
C_6	—*	.79 (N=13)	.77 (N=10)	.75 (N=10)	.81 (N=11)	

*These coders served as reliability coders during the same time block and were never paired with each other.

**Numbers in parentheses indicate the number of teaching sessions in which the coders were paired.

The levels of soliciting were defined by (a) the proportion of time spent on higher-order questions to that spent on the total number of questions, and (b) the use of high (more than 3 seconds) or low (less than three seconds) wait time. The reliability of only the proportion of higher-order questions was considered. The wait-time component of the soliciting variable was not coded because it proved impossible for the observers to monitor it. Similarly, the levels of reacting were distinguished by the proportion of time spent on high-reacting behaviors

TABLE 8

Intercoder Reliability of Amount of Time Spent on High Reacting Behaviors (Correlations above Diagonal) and Low-Reacting Behaviors (Correlations below Diagonal): Correlations B[illegible]een Coders' Observations of the Sa[illegible]ching Sessions

	[illegible]ers					
	C_1	C_2	C_3	C_4	C_5	C_6
C_1		.97 (N=12)**	.96 (N=10)	.99 (N=12)	.89 (N=13)	—*
C_2	.99 (N=12)		.99 (N=9)	—*	.95 (N=8)	.97 (N=13)
C_3	.89 (N=10)	.97 (N=9)		.99 (N=8)	—*	.95 (N=10)
C_4	.95 (N=12)	—*	.99 (N=8)		.95 (N=11)	.98 (N=10)
C_5	.81 (N=13)	.70 (N=8)	—*	.97 (N=11)		.99 (N=11)
C_6	—*	.93 (N=13)	.98 (N=10)	.99 (N=10)	.97 (N=11)	

*These coders served as reliability coders during the same time block and were never paired with each other.

**Numbers in parentheses indicate the number of teaching sessions in which the coders were paired.

to the total amount of time spent on reacting behaviors. The upper half of the matrix in Table 9 gives the intercoder correlations for the amount of time spent on higher-order questions divided by the total amount of time spent on questions. The lower half of the matrix presents the intercoder correlations for the amount of time spent on high-reacting behaviors divided by the total amount of time spent on reacting behaviors that were coded. The reliability of the soliciting dimension was moderately high; the average intercoder correlation was .81. The intercoder reliability of the reacting dimension was very high, with an average correlation of .99.

TABLE 9

Intercoder Reliability of Proportion of Time Spent on High Soliciting (Correlations above Diagonal) and Proportion of Time Spent on High Reacting (Correlations below Diagonal)**: Correlations Between Coders' Observations of the Same Teaching Session

	Coders					
	C_1	C_2	C_3	C_4	C_5	C_6
C_1		.97 (N=12)***	.71 (N=10)	.87 (N=12)	.71 (N=13)	—*
C_2	.99 (N=12)		.84 (N=9)	—*	.49 (N=8)	.86 (N=13)
C_3	.98 (N=10)	.99 (N=9)		.69 (N=8)	—*	.79 (N=10)
C_4	.99 (N=12)	—*	.99 (N=8)		.83 (N=11)	.64 (N=10)
C_5	.88 (N=13)	.96 (N=8)	—*	.99 (N=11)		.84 (N=11)
C_6	—*	.98 (N=13)	.99 (N=10)	.99 (N=10)	.99 (N=11)	

*These coders served as reliability coders during the same time block and were never paired with each other.

**Soliciting is here defined as the proportion of higher-order questions to the total number of questions; reacting is defined as the proportion of high reacting behaviors to the total number of reacting behaviors.

***Numbers in parentheses indicate the number of teaching sessions in which the coders were paired.

The average reliability of the coders' observations of each of the treatment variables is summarized in Table 10. The high average inter-coder correlations indicate that, for the most part, dependable measures of the fidelity of treatment implementation was obtained. Thus, the observation data can be used to ascertain whether the treatments were implemented as intended.

TABLE 10

Average Reliability of the Coders' Observations of Each of the Treatment Variables

Variable	Average Intercoder Correlation
Structuring	.99
Higher-Order Questions	.84
Lower-Order Questions	.79
High Reacting Behaviors	.98
Low Reacting Behaviors	.96
Soliciting	.81
Reacting	.99

Fidelity of Treatment Implementation

In this section we describe the degree to which the treatments as observed accorded with those intended. We present both average treatment profiles and treatment profiles for each teacher.

Average Treatment Profiles

The data from the observation instrument were grouped by treatment variation so that comparisons between the eight treatment variations could be made. The eight bar graphs in Figure 4 represent the average number of minutes of lesson duration and the average number of ten-second intervals spent on structuring, soliciting, and reacting behavior in each treatment variation.

Lesson duration. The observers recorded the times of starting and stopping each lesson. As can be seen in Figure 4, the average duration of lessons within treatment variations ranged from 38 minutes for the high structuring-high soliciting-high reacting (HHH) treatment to 30 minutes for the low structuring-low soliciting-low reacting (LLL) treatment. Accordingly, the lesson time for the total of nine lessons ranged from 342 minutes for HHH to 270 minutes for LLL. When average lesson

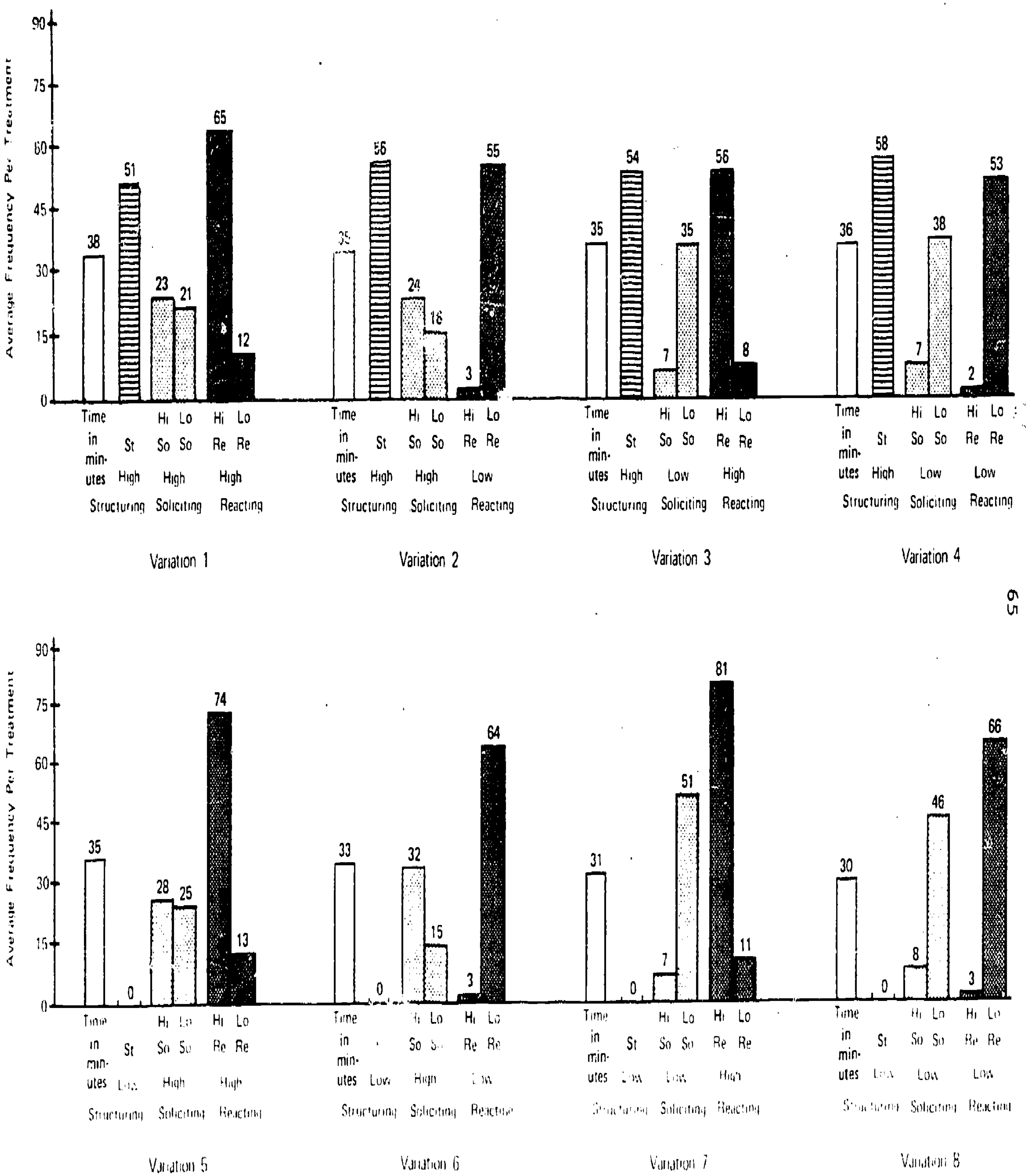

Fig. 4. Treatment Variations: Profiles showing the average number of minutes of teaching time and the average number of structuring, soliciting, and reacting 10-second intervals per treatment.

duration for the high level of one of the treatment variables was contrasted with average lesson duration for the low level of that same variable, the high lessons were, on the average, longer than the low variations. Lessons with high structuring averaged four minutes longer than lessons with low structuring. Lessons with high soliciting averaged two minutes longer than lessons with low soliciting. Lessons with high reacting averaged one minute longer than lessons with low reacting. Since nine lessons were taught to each class, students in high-structuring treatments received an average of 34 minutes more lesson time than students in low-structuring treatments; students in high-soliciting treatments received an average of 20 minutes more lesson time than students in low-soliciting treatments; and students in high-reacting treatments received an average of 11 minutes more lesson time compared to students in low-reacting treatments. The sum of these high-low differences (66 minutes) is less than that between HHH and LLL treatments (72 minutes) because the lesson-time differences resulting from the treatment variations are interactive and not merely the sum of the main effects.

Structuring. The teaching behaviors that constituted the structuring dimension of the treatment variations were clearly implemented as intended. The four high-structuring variations in Figure 4 had an average of 55 10-second intervals of structuring behavior recorded with a range of 58 to 51 10-second intervals per treatment. The profiles for the four variations with low structuring indicate that no structuring behaviors were observed. This dramatic contrast between high structuring and low structuring can be attributed to the fact that all structuring behaviors were explicitly written into the lesson plans in the high-structuring variations and completely omitted from the low-structuring lesson plans.

Soliciting. The lesson plans for the high soliciting treatments were characterized by an average of 59 percent higher-order questions and 41 percent lower-order questions. In contrast, the low soliciting lesson plans contained an average of 9 percent higher-order questions and 91 percent lower-order questions. When the proportions of higher- and lower-order questions in the lesson plans are compared with those in Figure 4, one finds that the levels of soliciting were implemented as intended.

According to Figure 4, teachers in the high-soliciting treatments devoted an average of exactly 58 percent of all 10-second intervals involving questions to higher-order questions and 42 percent to lower-order questions. In the low-soliciting treatments teachers devoted an average of 15 percent of all 10-second intervals involving questions to higher-order questions and 85 percent to lower-order questions. But these codings were based on time-intervals-spent rather than on the essential feature of this variable--nature of the question asked. Since the questions were scripted, and analysis of anecdotal records showed rare deviation from the script, the coded (time-based) observational data are only tangentially relevant. The low intercoder correlations are explained by the fact that the coders did not attend to the content development in the lesson--a significant basis for classifying questions as higher or lower order. Hence the coders could not be accurate judges of this variable. The bar graphs on soliciting thus underestimate the fidelity of implementation of the higher- versus lower-order questioning component of the soliciting variable.

Reacting. Figure 4 shows that in high reacting treatments the teachers engaged in a much higher average frequency of high-reacting behaviors than low-reacting behaviors (an average of 86 percent of all 10-second intervals devoted to reacting to high reacting and 14 percent to low reacting). In low reacting treatments, the opposite was true; that is, high reacting teacher behaviors were very rare (4 percent of all intervals devoted to reacting), and low reacting teacher behaviors were frequent (96 percent).

In summary, the average treatment profiles shown in Figure 4 indicate that the eight treatment variations did differ in the ways intended. When the frequency of a given kind of behavior should have been high, it was indeed high, and vice versa. The treatment variations also differed in the average duration of a lesson. This difference in time on task (i.e., duration of lessons) was intended only for the structuring treatment and will be taken into account when effects of the treatments are considered.

Treatment Profiles for Each Teacher

The data from the observational instrument were also examined separately for each teacher. Figures 5 through 8 show the frequency distributions of average number of minutes of teaching time and number of 10-second intervals devoted to structuring, soliciting, and reacting behaviors in each treatment for each teacher. Since each teacher taught each of the eight treatment variations to only one class, each bar graph (for example, the graph labeled "Variation 1" in Figure 5) represents the average observed frequencies for one class with one teacher over nine days.

Lesson duration. The longest average lesson duration was 41 minutes for Teacher 3 in Variation 1 (HHH), and the shortest average lesson duration was 25 minutes obtained by Teacher 4 teaching Variation 8 (LLL). When lesson duration was averaged across all variations for each teacher, it was found that Teacher 3 had the longest average lesson duration (38 minutes), followed by Teacher 1 (34 minutes), Teacher 4 (32 minutes), and Teacher 2 (31 minutes). The standard deviation of lesson duration for each teacher can be used as one index of the comparability of the eight treatment variations taught by the same teacher. Teacher 3 had the lowest standard deviation (2.5 minutes) for this variable, indicating that, for this teacher, the eight treatment variations were most similar in duration. The highest standard deviation for lesson duration was obtained by Teacher 4 (4.4 minutes). Teacher 1 had a standard deviation of 2.9 minutes, and Teacher 2 had a standard deviation of 2.7 minutes.

Structuring. In Figures 5 through 8, the contrast between treatment variations with high structuring and treatment variations with low structuring is as dramatic as that discussed above for all teachers combined. For the treatments with high structuring, Teacher 2 had the highest average number of 10-second intervals of structuring behavior (69), and Teacher 3 had the lowest average number (51). For the treatments with low structuring, the absence of structuring behavior is striking across all teachers. Only Teacher 1 allowed one or two 10-second intervals of structuring behavior to occur in these variations. The other three teachers appropriately avoided any structuring behavior at all in these treatments.

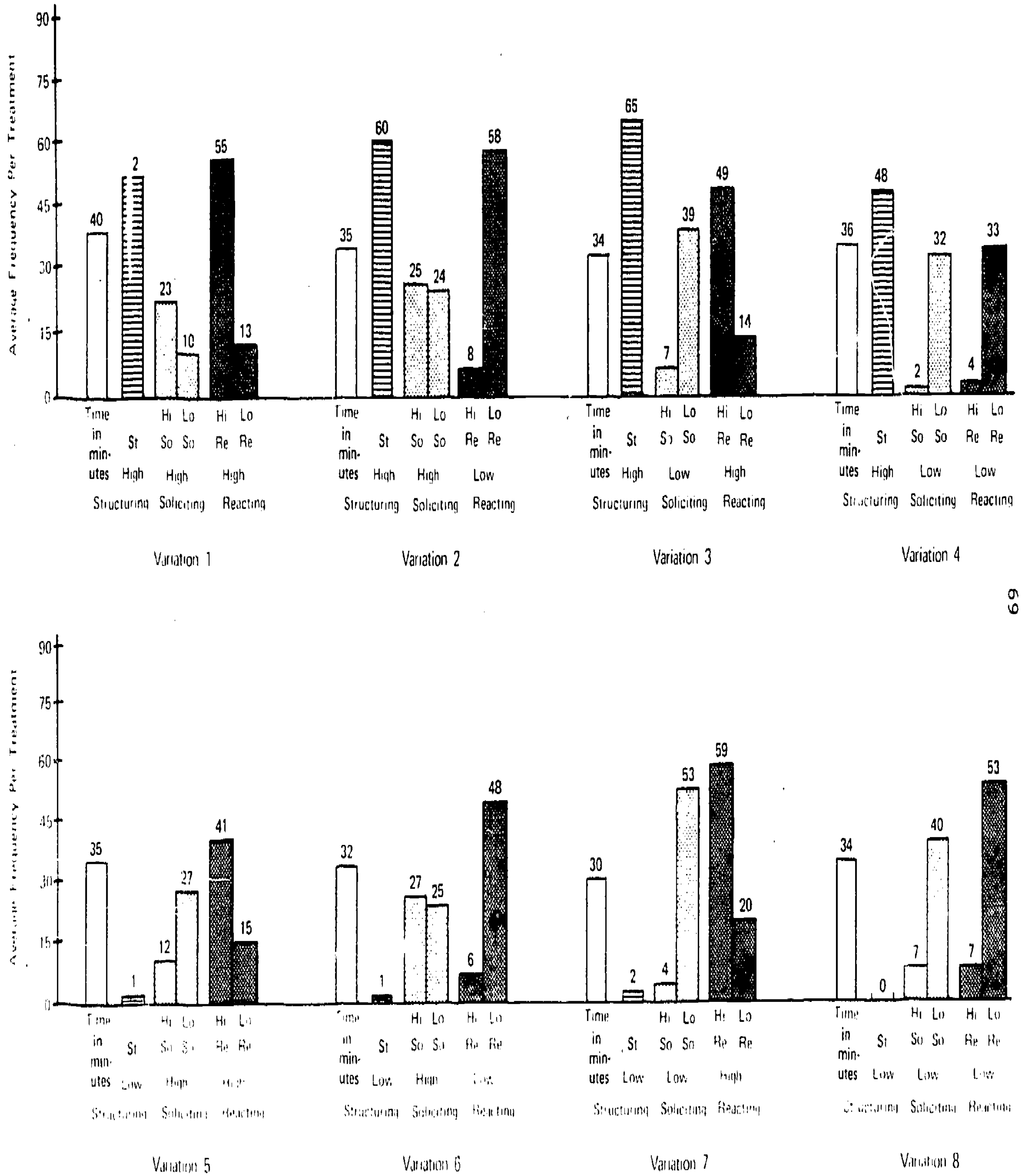

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Fig. 5. Treatment Variations for Teacher 1: Profiles showing the average number of minutes of teaching time and the average number of structuring, soliciting, and reacting 10-second intervals per treatment.

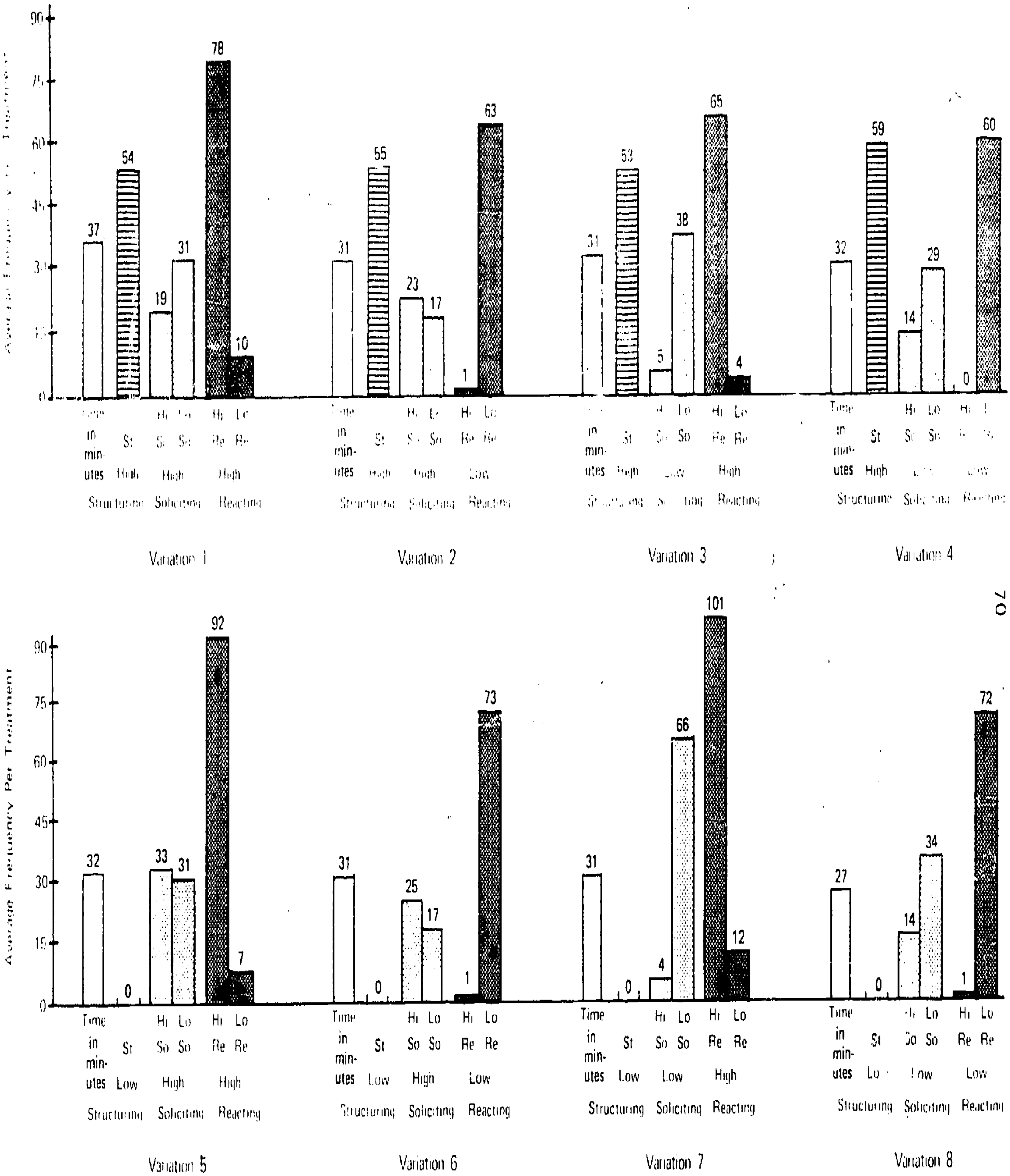


Fig. 6. Treatment Variations for Teacher 2: Profiles showing the average number of minutes of teaching time and the average number of structuring, soliciting, and reacting 10-second intervals per treatment.

Soliciting. In the treatment variations that included high soliciting, the average proportion of 10-second intervals devoted to higher-order questions asked by all teachers was greater than 50 percent of the total number of 10-second intervals devoted to questions. Teachers 1 and 2 had an average of 51 percent and 52 percent of question-asking 10-second intervals devoted to higher-order questions, respectively, in the high-soliciting treatment variations. Teacher 4 devoted an average of 65 percent of all 10-second intervals of questioning to higher-order questions, and Teacher 3 devoted an average of 67 percent in these treatments. In the treatment variations that included low soliciting, at least 80 percent of the intervals devoted to questions were devoted to lower-order questions. Teacher 2 used an average of 80 percent of all 10-second intervals on questions for lower-order questions in these treatments, Teacher 3 averaged 82 percent, and Teachers 1 and 4 both averaged 89 percent.

But it should be recalled, as indicated on page 67, that time spent was only a peripheral index of the implementation of the higher- versus lower-order questioning component of the soliciting variable.

Reacting. The bar graphs for the reacting variable indicate that this dimension of the treatment variations was well implemented by all teachers. For treatment variations with high reacting, the observers invariably recorded a much higher frequency of high-reacting behavior than of low-reacting behavior. In treatments with low reacting, the converse was true. The teachers differed markedly in the frequency of 10-second intervals devoted to high-reacting behaviors observed in the high-reacting treatment variations. Teacher 2 averaged 84 such intervals of high-reacting behavior in these treatments, while Teacher 1 averaged only 51. Teacher 3 averaged 70 intervals of high-reacting behavior and Teacher 4 averaged 72. These differences in amount of reacting behavior accorded with differences in the teachers' personalities noted in the anecdotal records. Those records indicated that Teacher 2 tended to be the most enthusiastic and effusive of the four teachers, while Teacher 1 was the least enthusiastic and effusive.

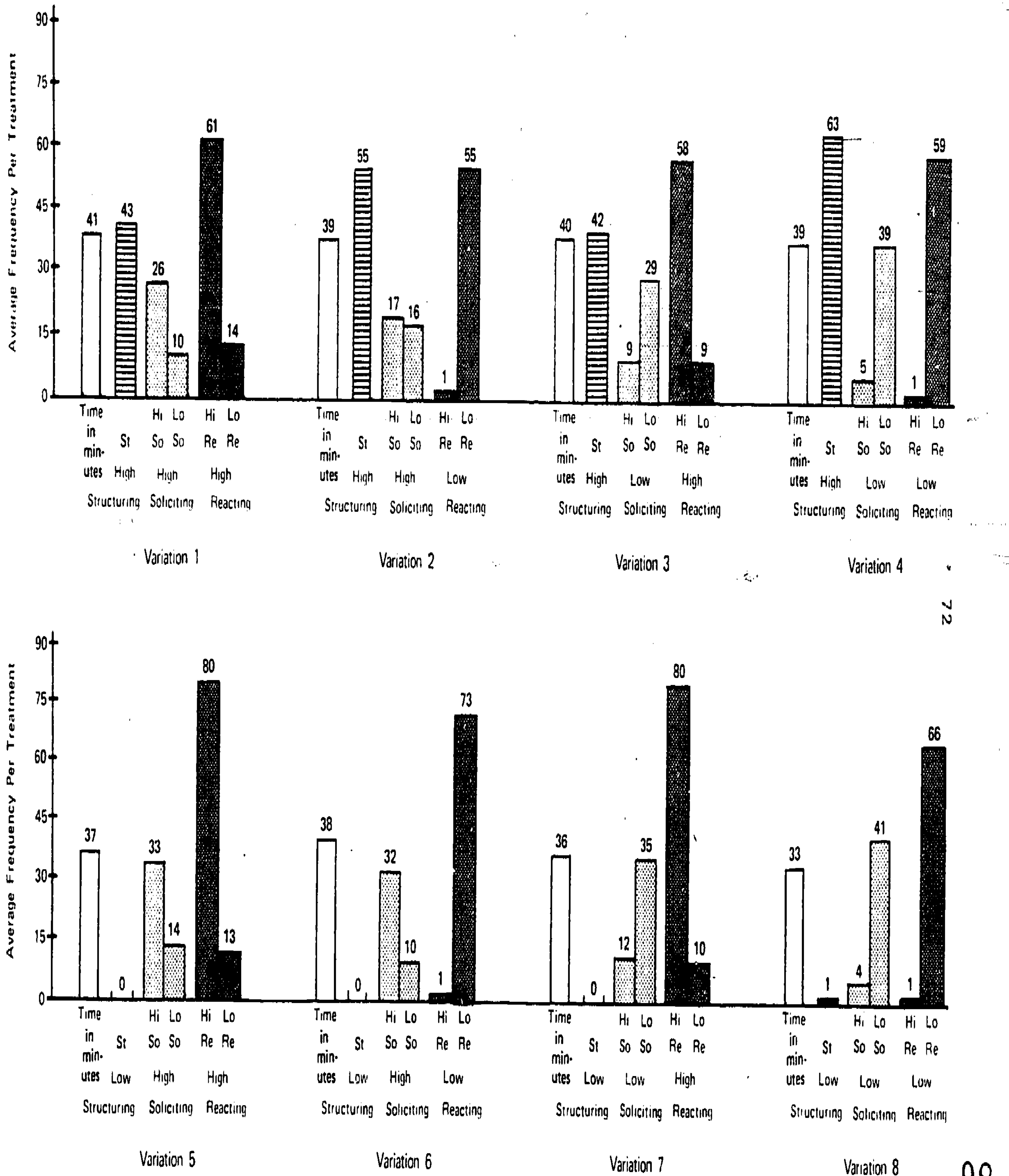
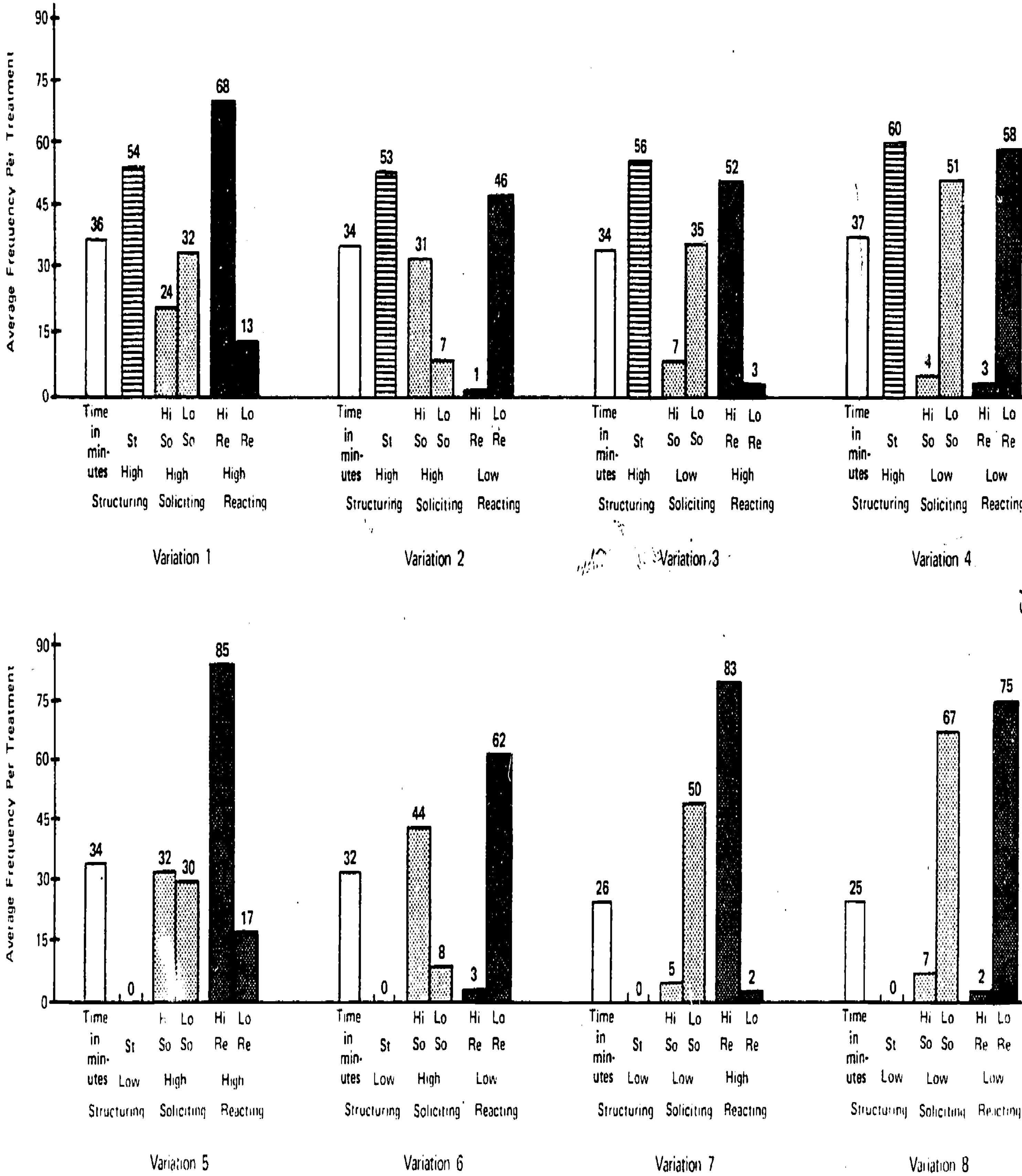


Fig. 7. Treatment Variations for Teacher 3: Profiles showing the average number of minutes of teaching time and the average number of structuring, soliciting, and reacting 10-second intervals per treatment.



73

Fig. 8. Treatment Variations for Teacher 4: Profiles showing the average number of minutes of teaching time and the average number of structuring, soliciting, and reacting 10-second intervals per treatment.

Analyses of Variance on Treatment Implementation

Analyses of variance were performed using the observation variables as the dependent variables and the treatment distinctions as the independent variables. The results provided further evidence that the treatments were implemented as intended.

Tables 11 through 15 present the results of these analyses of variance. The design of the analysis was a five-factor fully-crossed design with one repeated-measures factor. The five factors were structuring, soliciting, reacting, teacher, and lesson. The lesson factor was a repeated-measures factor. Since the design provided one observation per cell, the higher-order interactions were pooled to estimate the error term.

Table 11 shows the results of the analysis of variance on the observed structuring behaviors. As expected, there was a significant effect for structuring, with high structuring having significantly more structuring behaviors than low structuring. A significant lesson main effect and a lesson-by-structuring interaction also occurred. The lesson effect was expected because each of the lessons contained different ecological information, and the amount of structuring varied from lesson to lesson. The significant teacher-by-lesson interaction indicates that different teachers used different amounts of time for structuring from lesson to lesson. But, because the teachers were guided by scripts, structuring as measured by what was said was identical except for minor and presumably negligible errors. What varied was the time the teachers took to say the same things.

The results of the analyses of variance on higher-order and lower-order questions are presented in Tables 12 and 13, respectively. Both analyses revealed significant effects for soliciting of the kind intended. Furthermore, the nonsignificant differences for structuring and reacting indicate that higher- and lower-order questions were manipulated independently of the level of structuring or reacting. The significant lesson effects show that the frequency of intervals devoted to higher- and lower-order questions differed from lesson to lesson.

TABLE 11

Structuring Behaviors: Analysis of Variance on the Observed Frequency of Ten-second Intervals

Source		MS	F
Between Classes	31	6,810.294	
Structuring (STR)	1	205,600.800	1,086.811***
Soliciting (SOL)	1	116.281	0.61
Reacting (REA)	1	270.281	1.43
Teacher (TCHR)	3	134.096	0.71
Residual	25	189.178	
Within Classes	256	76.285	
Lesson	8	282.003	5.06**
Lesson x STR	8	249.598	4.48**
Lesson x SOL	8	67.938	1.22
Lesson x REA	8	30.625	0.55
Lesson x TCHR	24	139.773	2.51*
Residual	200	55.665	
Total	287	803.651	

*p < .05
**p < .01
***p < .001

TABLE 12

Higher-Order Questions: Analysis of Variance on the Observed Frequency of Ten-second Intervals

Source		MS	F
Between Classes	31	1,199.257	
Structuring (STR)	1	868.055	3.05
Soliciting (SOL)	1	27,730.130	97.44***
Reacting (REA)	1	231.125	0.81
Teacher (TCHR)	3	410.694	1.44
Residual	25	284.623	
Within Classes	256	107.877	
Lesson	8	523.633	5.98**
Lesson x STR	8	95.618	1.09
Lesson x SOL	8	261.279	2.99
Lesson x REA	8	80.984	0.93
Lesson x TCHR	24	100.9[illegible]	1.15
Residual	200	87.518	
Total	287	225.761	

*p < .05
**p < .01
***p < .001

TABLE 13

Lower-Order Questions: Analysis of Variance on the Observed Frequency of Ten-second Intervals

Source		MS	F
Between Classes	31	2,219.864	
Structuring (STR)	1	3,206.670	3.87
Soliciting (SOL)	1	38,665.160	46.64***
Reacting (REA)	1	1,480.587	1.79
Teacher (TCHR)	3	1,579.345	1.91
Residual	25	829.013	
Within Classes	256	124.734	
Lesson	8	1,136.932	13.369**
Lesson x STR	8	76.865	0.90
Lesson x SOL	8	290.863	3.42**
Lesson x REA	8	59.904	0.70
Lesson x TCHR	24	100.284	1.18
Residual	200	85.043	
Total	287	351.037	

*p < .05
**p < .01
***p < .001

Tables 14 and 15 present the results of the analyses of variance for low-reacting and high-reacting behaviors, respectively. The results show the predicted effects for reacting, lesson, and lesson-by-reacting interaction. But a significant effect for structuring also appeared. Inspection of the means revealed that the average frequency of intervals devoted to low-reacting behaviors was 32 in the high-structuring conditions and 39 in the low-structuring conditions. Similarly, the average frequency of intervals devoted to high-reacting behaviors was 32 in the high structuring variations and 40 in the low-structuring variations.

In other words, more reacting (either high or low) occurred with low structuring than with high structuring. Since the teachers had been directed to try to make the lessons of equal length, teachers in the low-structuring variations may have done more reacting in order to take up the time that was spent in structuring in the high-structuring condition. The use of higher- and lower-order questions was scripted. Thus the main flexibility was available in the number of times the teacher could react and redirect a question before giving the correct answer. Soliciting was unaffected by level of structuring, but reacting was significantly affected.

TABLE 14

Low-Reacting Behaviors: Analysis of Variance on the Observed Frequency of Ten-second Intervals

Source		MS	F
Between Classes	31	6,154.160	
Structuring (STR)	1	3,140.281	4.97*
Soliciting (SOL)	1	240.170	0.38
Reacting (REA)	1	169,895.900	269.12***
Teacher (TCHR)		573.429	0.91
Residual	25	631.293	
Within Classes	256	166.675	
Lesson	8	1,799.981	21.50**
Lesson x STR	8	58.079	0.69
Lesson x SOL	8	67.322	0.80
Lesson x REA	8	1,059.401	12.66**
Lesson x TCHR		85.103	1.02
Residual	200	83.740	
Total	287	813.407	

*p .05
**p < .01
***p < .001

TABLE 15

High-Reacting Behaviors: Analysis of Variance on the Observed Frequency of Ten-second Intervals

Source		MS	F.
Between Classes	31	11,533.813	
Structuring (STR)	1	5,092.086	4.77*
Soliciting (SOL)	1	61.420	0.06
Reacting (REA)	1	318,601.300	298.26***
Teacher (TCHR)	3	2,362.484	2.21
Residual	25	1,068.239	
Within Classes	256	226.514	
Lesson	8	1,540.917	11.45**
Lesson x STR	8	196.282	1.46
Lesson x SOL	8	112.660	0.84
Lesson x REA	8	1,403.763	10.43**
Lesson x TCHR	24	209.697	1.56
Residual	200	134.629	
Total	287	1,447.860	

$*p < .05$
$**p < .01$
$***p < .001$

In summary, the analyses of variance show that, with the exception of reacting, the treatment dimensions were manipulated independently. The structuring-by-reacting interaction in treatment implementation does not seriously affect the experiment.

Factors Affecting Interpretations

To determine the effects of the treatments on the achievement and attitudes of the students, analyses of variance and covariance were performed. These statistical methods rest on certain assumptions, whose validity can be determined empirically. In this section, we describe the empirical tests of those assumptions and certain other considerations in the treatment and interpretation of the data.

Tests of Statistical Assumptions

Before the analysis of covariance could be applied, it was necessary to determine whether the data met the assumptions of (a) homogeneity of variance in the various subgroups according to which the variance was to be partitioned, and (b) homogeneity of regression of the dependent variable on the covariate. When tests of the assumption of homogeneity of variance were made, the data shown in Tables 16 and 17 were obtained. The assumption of homogeneity of variance was met for all variables except the essay test. The variances of the raw scores on the essay achievement posttest ranged from .57 (for the students of Teacher 2 using the high-high-high treatment) to 10.8 (for the students of Teacher 4 using the high-high-high treatment). The value of Hartley's F_{max} statistic (Kirk, 1968, p. 62) was 18.92, indicating that the hypothesis that the variances were equal could be rejected at the .01 level.

To reduce the heterogeneity of variance, three types of transformation (Kirk, 1968, pp. 64-67) were examined:

(a) log transformation = $\log_{10}$ (essay test raw score + 1);

(b) square root transformation$_1$ = $\sqrt{\text{essay test raw score}} + \sqrt{\text{essay test raw score} + 1}$; and

(c) square root transformation$_2$ = $\sqrt{\text{essay test raw score} + 1/2}$

When the F_{max} statistics for these three transformations were computed, the values of F_{max} were 5.38, 5.07, and 5.92 for the three transformations listed above, respectively, for the essay achievement posttest scores. For the essay achievement retention test scores, the corresponding values were 10.15, 13.11, and 20.45. Since the log transformation yielded the lowest mean of the two F_{max} values, it was selected as the appropriate transformation for reducing the heterogeneity of variance of the essay achievement test scores.

TABLE 16

Tests of Homogeneity of Variance of the Posttest and Retention Variables with the Student as the Unit of Analysis (N = 386 Students)

Variable	Maximum Var/ Minimum Var	Cochran's C	Bartlett-Box F
Posttests			
Multiple-choice achievement total	8.10	.06	1.05
Text-and-teacher-as-source: lower-order subscale	8.73	.06	1.02
Text-and-teacher-as-source: higher-order subscale	10.08	.06	1.22
Teacher-only-as-source: lower-order subscale	4.50	.05	.93
Teacher-only-as-source: higher-order subscale	10.20	.06	1.27
Essay test on ecology[1]	5.38	.07	.69
Attitude-toward-ecology[1]	6.44	.07	1.11
Retention tests			
Multiple-choice retention total	8.26	.07	1.20
Text-and-teacher-as-source: lower-order subscale	5.98	.07	.81
Text-and-teacher-as-source: higher-order subscale	10.06	.07	1.45*
Teacher-only-as-source: lower-order subscale	8.25	.06	.80
Teacher-only-as-source: higher-order subscale	4.95	.07	1.03
Essay test on ecology[2]	10.15	.07	1.68**
Attitude-toward-ecology[2]	6.21	.05	1.08
True-False-? knowledge of ecology[2]	7.11	.06	.99

*$p < .05$ [1]N = 385
**$p < .01$ [2]N = 384

TABLE 17

Tests of Homogeneity of Variance of the Posttest and Retention Variables with the Half-Class as the Unit of Analysis (N = 32 half-classes)

Variable	Maximum Var/ Minimum Var	Cochran's C	Bartlett-Box F
Posttests			
Multiple-choice achievement total	13.39	.40	1.09
Text-and-teacher-as-source: lower-order subscale	8.83	.23	.57
Text-and-teacher-as-source: higher-order subscale	26.27	.46*	1.40
Teacher-only-as-source: lower-order subscale	8.37	.33	.87
Teacher-only-as-source: higher-order subscale	18.48	.42	1.13
Essay Test on ecology	40.53	.43*	1.31
Attitude-toward ecology	26.16	.28	1.24
Retention tests			
Multiple-choice retention total	5.88	.30	.55
Text-and-teacher-as-source: lower-order subscale	20.19	.25	1.15
Text-and-teacher-as-source: higher-order subscale	18.82	.31	1.05
Teacher-only-as-source: lower-order subscale	6.47	.20	.43
Teacher-only-as-source: higher-order subscale	9.27	.29	.61
Essay test on ecology	13.19	.35	1.11
Attitude-toward-ecology	11.97	.35	.87
True-False-? knowledge of ecology	7.46	.25	.54

*p < .05

Accordingly, the essay test scores were subjected to a logarithmic transformation whereby:

$$\text{Transformed essay test score} = \log_{10} (X + 1),$$

where X is the raw essay test score. This transformation was applied to the essay test scores of individual students and not to the mean essay test scores of half-classes. Table 18 shows the descriptive statistics for the raw and transformed essay achievement posttest and retention test scores. The considerable reduction in skewness resulting from the transformation is evident.

TABLE 18

Descriptive Statistics for the Distributions of Raw and Log-Transformation Essay Achievement Posttest and Retention Test Scores

	Posttest		Retention Test	
	Raw Score	Log-Transformation	Raw Score	Log-Transformation
Mean	1.71	0.353	.99	0.207
Median	1.30	0.316	.41	0.019
Mode	1.00	0.301	.00	0.000
S.D.	1.73	0.264	1.59	0.260
Skewness (normal = 0)	1.45	0.119	2.62	0.946 (positive skew)
Range	10	1.041	12	1.114

Tests for the homogeneity of regression of the multiple-choice achievement test scores on the vocabulary pretest scores were made for each of the 32 half-classes. These tests showed that the regressions were not homogeneous. They ranged from -.51 to 1.58. To investigate further the properties of the relationship between the vocabulary and multiple-choice tests, a number of additional half-class statistics were obtained; the means, standard deviations, curvilinear regression coefficient, and measures of the increase in the variance accounted for when the curvilinear component was added to the linear component of the regression of the achievement posttest on the vocabulary pretest. These statistics are shown in Table 19. It should be noted that the half-class that received the HLH treatment from Teacher 1 shows a negative regression coefficient of -.51 and has the smallest standard deviation on both the vocabulary pretest and the multiple-choice achievement posttest. Also, the half-class taught with the LLH treatment by Teacher 2 had a linear regression that accounted for 1 percent of the variance and a curvilinear regression that accounted for 63 percent of the variance.

These results raised questions about the homogeneity of regression within the 32 half-classes. Accordingly, the scatter plots of these two variables in each of the 32 half-classes were examined. These scatter plots revealed many "outliers" and led to a search for anomalies that might account for them. This search was based on three kinds of data: records of absences of individual students from class on specific days; anecdotal records kept by the research workers on each day's class session, and the test booklets of individual students which revealed their response patterns in taking the vocabulary pretest and the multiple-choice achievement posttest.

The following criteria for eliminating invalid cases were considered:

a. Absence from class for three or more of the nine days during which instruction was conducted, or missing Day Five, on which the teacher presented a review and summary of the lessons up to that point.

b. Evidence in the anecdotal record indicating that the student had been a discipline problem, failing to pay attention, causing disruptions, and otherwise showing evidence of unwillingness or inability to pay attention and learn from the instruction provided. In some cases, the student's regular teacher indicated that the student had a language problem (inability to comprehend English in a normal way) or a short attention span.

c. Indications in the test booklets that the student had been unable or unwilling to respond to all of the items in what seemed to be a rational or well-motivated way. For example, some students failed to answer questions on entire pages of the test booklet, perhaps through the accident of turning more than one page at a time. Several students could be seen to have copied from one another because their answer patterns were identical. Other students had response patterns such that only one response alternative was chosen for all of the items on a given page of the text.

TABLE 19

Means and Standard Deviations of the Individual Students' Scores of the 32 Half-Classes on the Vocabulary Pretest and the Multiple-Choice Achievement Posttest and Their Relationship

Treatment	Teacher	N	Vocabulary $\bar{X}$	Vocabulary SD	Multiple-Choice Posttest $\bar{Y}$	Multiple-Choice Posttest SD	Slope b_{yx}	r^2_{xy}
HHH	1	13	23.6	6.79	22.5	6.53	.80	.69
HHH	2	15	19.5	5.62	18.5	6.20	.71	.41
HHH	3	12	22.9	4.60	19.7	5.99	.97	.56
HHH	4	13	22.5	6.29	20.8	6.51	.66	.41
HHL	1	14	22.0	4.66	21.4	5.33	.48	.17
HHL	2	12	23.8	3.49	22.2	5.17	1.32	.79
HHL	3	15	19.6	5.64	18.3	5.22	.45	.23
HHL	4	13	21.1	6.95	19.4	6.01	.61	.49
HLH	1	13	24.8	2.51	26.8	2.76	-.51	.21
HLH	2	10	23.3	3.62	20.8	3.82	.61	.34
HLH	3	11	22.2	3.95	20.6	5.12	1.14	.77
HLH	4	12	24.2	5.29	24.0	5.56	.77	.54
HLL	1	13	17.9	3.20	18.5	7.46	1.03	.19
HLL	2	11	18.2	6.97	20.9	4.06	.33	.33
HLL	3	16	22.4	5.18	21.9	6.14	.76	.41
HLL	4	10	21.4	[illegible].32	20.8	5.05	.49	.27
LHH	1	11	16.5	3.88	19.4	5.05	.78	.36
LHH	2	13	21.0	4.40	19.8	4.75	.85	.62
LHH	3	10	19.9	6.26	16.9	7.87	.81	.42
LHH	4	12	19.3	4.75	19.0	5.49	.60	.27
LHL	1	14	18.1	5.61	16.9	6.25	.58	.27
LHL	2	13	21.3	3.97	20.2	4.22	.53	.25
LHL	3	12	25.8	3.96	21.3	5.43	.42	.09
LHL	4	10	22.3	4.40	19.6	7.20	.99	.37
LLH	1	11	18.8	7.36	20.4	5.59	.49	.41
LLH	2	11	25.0	3.19	26.4	2.80	.10	.01
LLH	3	9	15.8	6.52	17.4	5.43	.59	.50
LLH	4	11	20.5	3.36	18.9	4.51	-.18	.02
LLL	1	14	21.3	6.97	19.7	5.44	.56	.51
LLL	2	8	23.8	4.62	21.5	7.71	.98	.34
LLL	3	12	19.1	5.21	19.1	4.62	.26	.07
LLL	4	12	21.6	4.78	20.8	6.38	1.25	.88
Total		386	21.2	5.50	20.4	5.82	.65	.38

After due consideration, we decided that the only legitimate criterion we could use to eliminate invalid cases was student absences. Criterion b was rejected because we felt that the external validity of our experiment would be greatly impaired if we eliminated students who had been discipline problems or who had failed to pay attention. Criterion c was rejected because both the vocabulary and the multiple-choice tests were timed, and students could have failed to respond to whole pages because they did not have enough time or were following the instructions not to guess. Similarly, the evidence suggesting copying or irrational response patterns was not conclusive enough to justify elimination of any students.

Thus, for the final analysis, we eliminated only the 22 students who had missed three or more of the nine days of instruction. All analyses were recomputed on the reduced set of 386 cases. An F test of the homogeneity of regression of the multiple-choice achievement test scores on the vocabulary test scores across the 32 half-classes yielded a nonsignificant F value of 1.07, with 31 and 322 df. Similarly, Table 20 shows the homogeneity of regression of the treatment groups each with half classes. Here, the F test of homogeneity of regression yielded an F value of 2.18, which with 7 and 16 degrees of freedom was not significant at the .05 level.

Fixed vs. Random Effects

The design of the present experiment allows a four-way analysis of variance or analysis of covariance. The four factors are (a) structuring, (b) soliciting, (c) reacting, and (d) the teacher. The three treatment factors (structuring, soliciting, and reacting) are considered to be fixed factors because they exhaust all levels of the factor to which generalizations are to be made. It would be interesting to investigate intermediate levels of these factors, but that possibility is of no concern in this study. The teacher factor (with four levels corresponding to each of the four experimental teachers) is considered to be a random effect in the present analysis.

The decision to treat teachers as a random effect was made despite the argument that there was no random selection of teachers, since they

TABLE 20

Means and Standard Deviations of the Half-Class Means of the Eight Treatments on the Vocabulary Pretest and the Multiple-Choice Achievement Posttest, and Their Relationship
(N = 4 half-classes per treatment)

Treatment	Vocabulary $\bar{X}$	Vocabulary SD	Multiple-Choice Posttest $\bar{X}$	Multiple-Choice Posttest SD	Slope b_{yx}	Variance accounted for r^2_{xy}
HHH	22.1	1.81	20.4	1.70	.78	.70
HHL	21.6	1.76	20.3	1.79	.98	.92
HLH	23.6	1.13	23.1	2.95	2.38	.84
HLL	20.0	2.26	20.5	1.44	.47	.55
LHH	19.2	1.92	18.8	1.29	-.10	.02
LHL	21.9	3.17	19.5	1.87	.55	.86
LLH	20.0	3.84	20.8	3.95	.94	.84
LLL	21.5	1.92	20.3	1.08	.52	.87
Total	21.2	2.49	20.5	2.26	.67	.55

were selected on the basis of well-defined criteria and were intensively trained for two weeks. The argument for considering teachers to be a random factor was that it would be inadequate to generalize the results to only the four teachers used in the present study.* Such a limitation would restrict the conclusions so greatly that they would be of little value. Considering teachers as a fixed effect would not allow generalization of the results of this study to other teachers similarly selected and trained.

Since this study was intended to investigate the effects of teacher behaviors on student achievement, the vehicle for presentation of these behaviors (i.e., the teacher) was considered to be of secondary interest. It offered no helpful theoretical explanations for observed differences in student achievement. In fact, the selection and training of teachers

*We are grateful to Andrew C. Porter for clarification of this issue.

were expressly intended to reduce as much as possible the variation between teachers in the teaching behaviors being investigated. Since the teachers were considered to be "interchangeable" in this experiment, they were considered to represent a sample from a population of teachers with similar characteristics (i.e., age, sex, experience, etc.) and training. Thus, it was concluded that teachers should be considered a random effect, and that generalizations would apply to all teachers who had characteristics similar to those used in this study.

Table 1 in Appendix E presents the equations for the expected mean squares for the four-way anova with teacher considered a random effect. The error terms for testing the significance of the sources of variance in the design are listed in the right-hand column of this table.

Student vs. Half-Class as Unit of Analysis

It could be argued that the student should be used as the unit of analysis because achievement was, after all, measured on the basis of the performance of individual students acting independently of one another. Similarly, it could be argued that the learning process goes on within the individual student, even though the half-class is seemingly taught as an entire group. Thus, intra-half-class differences among students in level of participation, involvement in class activities, interaction with the teacher, relationships with fellow students, and the like, would tend to make the achievement of individual students become independent of that of other students, even those within the same half-class. Further, it could be argued that the student should be used as the unit of analysis because responses to the treatment variables, such as soliciting or reacting, cannot be considered to be uniform within the half-class; rather, it is reasonable to suppose that these responses differ from one student to another within the same half-class as a function of students' different perceptions, sensitivities, and expectations.

On the other hand, it could be argued that the half-class should be used as the unit of analysis because the experimental variables were administered on a half-class basis and were not differentiated for the individual students within a class. The treatments were intended to have an effect on half-class means, by this argument, rather than on the scores of individual students. Thus, in this view, the variance in achievement within half-classes is a kind of "noise" irrelevant to the kinds of effects that the experimental variables might be expected to bring about.

The obviously desirable resolution of this issue is to use both kinds of analysis and to see whether they yield the same results or, if they yield different results, to see whether the differences can be interpreted in some sensible way. And, indeed, we did perform both kinds of analysis.

The Inflation of Probabilities

In the following presentation and discussion of results, many tests of statistical significance will be presented. As is well known, if many tests of statistical significance are performed, and the criterion of $p \leq .05$ is set for statistical significance, 5 percent of the tests will indicate statistical significance simply as a result of chance fluctuations in random sampling. But the estimate that 5 percent of the results will turn out to be significant simply as a result of errors of Type I holds only when the significance tests are experimentally independent of one another. In the present data, such independence cannot be claimed. Many of the dependent variables were correlated with one another, as we have seen. In some cases the dependent variables are parts of a whole, and in some cases the same data were analyzed with the half-class as the unit of analysis and also with the individual student as the unit of analysis. All of these considerations should greatly increase our conservatism in the interpretation of the results. The findings should be considered to have only suggestive value. The surest source of conviction about any findings of the kinds considered here is independent replication of the experiment.

Descriptive Statistics on the Pretest Variables

To what extent did the treatment groups differ on the dimensions measured by the various pretests? We consider this question for each of the pretests in turn.

Vocabulary

Table 21 shows the means and standard deviations of the scores on the vocabulary test for the several school districts, schools, classes, and half-classes. It should be noted that, at the class and half-class level, the differences in means were sometimes substantial. The class means ranged from 15.78 to 24.85. Similarly, the means for the half-classes ranged from 15.78 to 25.75. For a test with 35 items and an overall mean and standard deviation of 21.23 and 5.50, respectively, these differences of nearly 10 points between the highest and lowest class and half-class means show that the effort to make the classes and half-classes equivalent in scholastic ability was only moderately successful. Despite assurances from school authorities that the schools did not practice homogeneous grouping, the differences between classes within schools were often so great as to make such homogeneous grouping the only plausible explanation. For example, in School A, the class means ranged from 18.23 to 24.57. Similarly, in School I, the three classes had means of 15.78, 19.96, and 24.85, strongly suggesting some homogeneous grouping. Even when the intact classes were divided by the investigators at random into two half-classes, some fairly substantial differences between half-classes appeared. Thus, the difference between Half-Classes 11 and 12 was greater than four points, and that between Half-Classes 19 and 20 was more than five points. Thus, also, Classes 29 and 30 consisted of the sixth graders selected from a class consisting of both fifth and sixth graders. In Class 29, these sixth graders drawn from the mixed class turned out to have a mean vocabulary score of 15.78. But in Half-Class 30, which also consisted of the sixth-graders drawn from a mixed class, the sixth graders turned out to have a mean vocabulary score of 24.85. Thus, although the investigators had been given no warning that homogeneous grouping had been applied in the assigning of students to these classes within the same school, the result was that Half-Classes 29 and 30 differed by more than nine points on the vocabulary test.

Table 22 shows the statistics on the vocabulary test for the various treatments and teachers. Reading this table from right to left, we note that the differences between the high and low groups on reacting,

TABLE 21

Means and Standard Deviations of Scores on the Vocabulary Pretest by District, School, Class, and Half-Class (standard deviations in parentheses)

District	School		Class		Half-Class		N
I — 20.38 (5.32)	A	20.38 (5.32)	a	18.23 (5.11)	1	19.53 (5.62)	15
					2	16.46 (3.88)	11
			b	20.68 (5.26)	3	22.30 (4.40)	10
					4	19.60 (5.64)	15
			c	24.57 (4.34)	5	25.00 (3.19)	11
					6	24.17 (5.29)	12
			d	18.48 (4.23)	7	19.08 (5.21)	12
					8	17.92 (3.20)	13
II — 21.93 (5.47)	B	22.80 (5.88)	e	22.31 (5.76)	9	23.62 (6.79)	13
					10	21.00 (4.40)	13
			f	23.32 (6.08)	11	25.75 (3.96)	12
					12	21.08 (6.95)	13
	C	21.81 (3.70)	g	20.46 (3.36)	13	20.46 (3.36)	11
			h	23.30 (3.62)	14	23.30 (3.62)	10
	D	21.90 (6.00)	i	21.29 (6.97)	15	21.29 (6.97)	14
			j	22.44 (5.18)	16	22.44 (5.18)	16
	E	21.42 (5.27)	k	22.92 (4.60)	17	22.92 (4.60)	12
	H*	20.92 (4.50)	l	19.25 (4.75)	18	19.25 (4.75)	12
	E		m	20.73 (5.50)	19	18.07 (5.61)	14
					20	23.83 (3.49)	12
	F	21.38 (5.61)	n	20.50 (6.01)	21	18.82 (7.36)	11
					22	22.18 (3.95)	11
			o	22.44 (5.02)	23	23.75 (4.62)	8
					24	21.40 (5.32)	10
III — 20.85 (5.59)	G	21.35 (6.27)	p	21.35 (6.27)	25	22.46 (6.29)	13
					26	19.90 (6.26)	10
	H	20.92 (4.50)	q	21.67 (4.27)	27	21.31 (3.97)	13
					28	22.00 (4.66)	14
	I	20.53 (6.16)	r	15.78 (6.52)	29	15.78 (6.52)	9
			s	24.85 (2.51)	30	24.85 (2.51)	13
			t	19.96 (6.04)	31	21.58 (4.78)	12
					32	18.18 (6.97)	11

*School H is in District III

TABLE 22

Means and Standard Deviations of Scores on the Vocabulary Test by Treatment and Teacher

STR X SOL X REA X TCHR					STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
TRMT	TCHR	X	S.D.	N							
HHH	1	23.62	6.79	12	HHH:						
	2	19.53	5.62	15	$\bar{X}$ = 22.01						
	3	22.92	4.60	12	SD = 5.95	HH*:	H*H	*HH			
	4	22.46	6.29	13	N = 53	$\bar{X}$ = 21.77	$\bar{X}$ = 22.80	$\bar{X}$ = 20.72			
HHL	1	22.00	4.66	14	HHL:	SD = 5.67	SD = 5.17	SD = 5.67			
	2	23.83	3.49	12	$\bar{X}$ = 21.52	N = 107	N = 99	N = 99			
	3	19.60	5.64	15	SD = 5.44				H**:	*H*:	**H:
	4	21.08	6.95	13	N = 54				$\bar{X}$ = 21.80	$\bar{X}$ = 21.16	$\bar{X}$ = 21.34
HLH	1	24.85	2.51	13	HLH:				SD = 5.40	SD = 5.50	SD = 5.56
	2	23.30	3.62	10	$\bar{X}$ = 23.70				N = 203	N = 202	N = 187
	3	22.18	3.95	11	SD = 3.96	HL*:	H*L:	*HL:			
	4	24.17	5.29	12	N = 46	$\bar{X}$ = 21.83	$\bar{X}$ = 19.69	$\bar{X}$ = 21.59			
HLL	1	17.92	3.20	13	HLL:	SD = 5.11	SD = 5.55	SD = 5.33			
	2	18.18	6.97	11	$\bar{X}$ = 20.12	N = 96	N = 88	N = 103			
	3	22.44	5.18	16	SD = 5.48						
	4	21.40	5.32	10	N = 50						
LHH	1	16.46	3.88	11	LHH:						
	2	21.00	4.40	13	$\bar{X}$ = 19.22						
	3	19.90	6.26	10	SD = 4.98	LH*:	L*H:	*LH:			
	4	19.25	4.75	12	N = 46	$\bar{X}$ = 20.48	$\bar{X}$ = 20.85	$\bar{X}$ = 22.03			
LHL	1	18.07	5.61	14	LHL:	SD = 5.25	SD = 5.48	SD = 5.38			
	2	21.31	3.97	13	$\bar{X}$ = 21.67	N = 95	N = 104	N = 88	L**:	*L*:	**L:
	3	25.75	3.96	12	SD = 5.27				$\bar{X}$ = 20.61	$\bar{X}$ = 21.31	$\bar{X}$ = 21.14
	4	22.30	4.40	10	N = 49				SD = 5.55	SD = 5.50	SD = 5.45
LLH	1	18.82	7.36	11	LLH:				N = 183	N = 184	N = 199
	2	25.00	3.19	11	$\bar{X}$ = 20.21						
	3	15.78	6.52	9	SD = 6.14	LL*:	L*L:	*LL:			
	4	20.46	3.36	11	N = 42	$\bar{X}$ = 20.74	$\bar{X}$ = 21.45	$\bar{X}$ = 20.65			
LLL	1	21.29	6.97	14	LLL:	SD = 5.88	SD = 5.43	SD = 5.56			
	2	23.75	4.62	8	$\bar{X}$ = 21.22	N = 88	N = 95	N = 96			
	3	19.08	5.21	12	SD = 5.65						
	4	21.58	4.78	12	N = 46						

soliciting, and structuring seem very small, amounting in no case to more than 1.19 points (mean for high structuring = 21.80; mean for low structuring = 20.61). Similarly, the four groups resulting from the first-order interactions between soliciting and reacting, structuring and reacting, and structuring and soliciting, respectively, also differed. Here, however, some of the differences appeared to be substantial. For example, the difference between the low soliciting-low reacting group and the low soliciting-high reacting group was 1.38. The difference between the high structuring-high reacting group and the high structuring-low reacting group was 3.11. And the difference between the high structuring-low soliciting and the low structuring-high soliciting groups was 1.35. Finally, when the second-order interaction groups are considered, we find the range in the mean vocabulary test scores extending from 19.22 for the LHH group to 23.70 for the HLH group. This difference of 4.48 points suggests that these eight groups cannot be considered equivalent in scholastic ability. But these differences also may reflect merely the chance fluctuations resulting from the imperfect reliability of the vocabulary test. Thus they may not exceed the variability that the test's standard error of measurement would lend one to expect by chance.

These initial differences between the half-classes in vocabulary test mean scores suggest the desirability of adjusting the achievement test scores for the initial differences between classes in scholastic aptitude (vocabulary). Such adjustment through analysis of covariance was used to improve the precision of the examination of treatment effects on student achievement. Vocabulary scores served as the covariate.

True-False-? Knowledge of Ecology Pretest

Table 23 shows the statistics for the pretest scores on the True-False-? test of knowledge of ecology. Table 24 shows the means and standard deviations of the scores on this inventory for each of the treatments, combinations of treatments, and teachers. As shown in Table 23, the range of the means of the half-classes extends from 5.73 (for Half-Class 13) to 10.08 (for Half-Class 25). The difference of 4.35 points on this 20-item test seems substantial and again suggests that the classes were not equivalent in their knowledge of ecology. Although

TABLE 23

Means and Standard Deviations of Scores on the True-False-? Knowledge of Ecology Pretest by District, School, Class, and Half-Class
(standard deviations in parentheses)

District	School		Class		Half-Class		N
I — 7.89 (2.65)	A	7.89 (2.65)	a	7.81 (2.58)	1	8.07 (2.76)	15
					2	7.46 (2.38)	11
			b	7.40 (2.16)	3	7.00 (2.06)	10
					4	7.67 (2.26)	15
			c	8.17 (3.04)	5	7.82 (2.82)	11
					6	8.50 (3.32)	12
			d	8.20 (2.87)	7	7.25 (2.63)	12
					8	9.08 (2.90)	13
II — 7.11 (2.61)	B	7.00 (2.43)	e	7.12 (2.64)	9	6.31 (2.56)	13
					10	7.92 (2.57)	13
			f	6.88 (2.22)	11	7.92 (2.07)	12
					12	5.92 (1.98)	13
	C	6.14 (2.80)	g	5.73 (2.65)	13	5.73 (2.65)	11
			h	6.60 (3.03)	14	6.60 (3.03)	10
	D	7.50 (2.70)	i	6.79 (2.99)	15	6.79 (2.99)	14
			j	8.13 (2.36)	16	8.13 (2.34)	16
	E	7.40 (2.54)	k	7.00 (2.86)	17	7.00 (2.86)	12
	H*		l	8.83 (2.08)	18	8.83 (2.08)	12
	E		m	7.58 (2.42)	19	6.93 (2.50)	14
					20	8.33 (2.19)	12
	F	7.18 (2.71)	n	7.82 (2.89)	21	8.18 (2.27)	11
					22	7.46 (3.48)	11
			o	6.39 (2.30)	23	6.50 (2.07)	8
					24	6.30 (2.58)	10
III — 8.00 (2.73)	G	8.87 (2.99)	p	8.87 (2.99)	25	10.08 (2.87)	13
					26	7.30 (2.45)	10
	H	8.10 (2.32)	q	7.78 (2.38)	27	7.54 (2.22)	13
					28	8.00 (2.57)	14
	I	7.47 (2.85)	r	6.67 (4.00)	29	6.67 (4.00)	9
			s	8.54 (3.07)	30	8.54 (3.07)	13
			t	7.17 (2.06)	31	7.50 (2.20)	12
					32	6.82 (1.94)	11

*School H is in District III

TABLE 24

Means and Standard Deviations of Scores on the True-False-? Knowledge of Ecology Pretest by Treatment and Teacher

TRMT	TCHR	X	S.D.	N	STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH	1	6.31	2.56	13	HHH:						
	2	8.07	2.76	15	$\bar{X}$ = 7.89						
	3	7.00	2.86	12	SD = 3.04	HH*:	H*H:	*HH:			
	4	10.08	2.87	13	N = 53	$\bar{X}$ = 7.68	$\bar{X}$ = 7.87	$\bar{X}$ = 7.90			
						SD = 2.72	SD = 3.11	SD = 2.74			
HHL	1	8.00	2.51	14	HHL:	N = 1.07	N = 99	N = 99			
	2	8.33	2.19	12	X = 7.48						
	3	7.67	2.26	15	SD = 2.39				H**:	*H*:	**H:
	4	5.92	1.98	13	N = 54				$\bar{X}$ = 7.73	$\bar{X}$ - 7.65	$\bar{X}$ = 7.71
									SD = 2.80	SD = 2.52	SD = 2.92
HLH	1	8.54	3.07	13	HLH:				N = 203	N = 202	N = 187
	2	6.60	3.03	10	$\bar{X}$ = 7.85						
	3	7.46	3.48	11	SD = 3.22	HL*:	H*L:	*HL:			
	4	8.50	3.32	12	N = 46	$\bar{X}$ = 7.78	$\bar{X}$ = 7.53	$\bar{X}$ = 7.42			
						SD = 2.91	SD = 2.71	SD = 2.29			
HLL	1	9.08	2.90	13	HLL:	N = 96	N = 88	N = 103			
	2	6.82	1.94	11	$\bar{X}$ = 7.72						
	3	8.13	2.34	16	SD = 2.62						
	4	6.30	2.58	10	N = 50						
LHH	1	7.46	2.38	11	LHH:						
	2	7.92	2.57	13	$\bar{X}$ = 7.91						
	3	7.30	2.45	10	SD = 2.37	LH*:	L*H:	*LH:			
	4	8.83	2.08	12	N = 46	X = 7.62	$\bar{X}$ = 7.60	X = 7.50			
						SD = 2.29	SD = 2.49	SD = 3.12			
LHL	1	6.93	2.50	14	LHL:	N = 95	N = 104	N = 88			
	2	7.54	2.22	13	$\bar{X}$ = 7.35						
	3	7.92	2.07	12	SD = 2.20				L**:	*L*:	**L:
	4	7.00	2.06	10	N = 49				$\bar{X}$ = 7.36	$\bar{X}$ = 7.45	$\bar{X}$ = 7.41
									SD = 2.53	SD = 2.84	SD = 2.43
LLH	1	8.18	2.27	11	LLH:				N = 183	N = 184	N = 199
	2	7.82	2.82	11	$\bar{X}$ = 7.12						
	3	6.67	4.00	9	SD = 3.01	LL*:	L*L:	*LL:			
	4	5.73	2.65	11	N = 42	$\bar{X}$ = 7.08	$\bar{X}$ = 7.20	$\bar{X}$ = 7.40			
						SD = 2.74	SD = 2.35	SD = 2.57			
LLL	1	6.79	2.99	14	LLL:	N = 88	N = 95	N = 96			
	2	6.50	2.07	8	$\bar{X}$ = 7.04						
	3	7.25	2.63	12	SD = 2.50						
	4	7.50	2.20	12	N = 46						

most of the half-class means fell within the range from 6.00 to 8.50, with only two half-classes falling below this range and four others above it, even this majority seems to vary fairly substantially in initial knowledge about ecology. Similar analysis of the means on the True-False-? pretest of knowledge of ecology, for each of the various treatment groups, is shown in Table 24. Here, the differences for the three major treatment variables considered alone are small, amounting to less than .50. For the first-order combinations of the treatment variables, some of the differences between means are larger. For example, the high structuring-low soliciting group had a mean of 7.78 while the low-structuring and low-soliciting group had a mean of 7.08. Nonetheless, these treatment groups seemed to be fairly equivalent on this pretest variable. When the eight treatment groups are considered separately, the means on the True-False-? test range from 7.04 to 7.91. Here, again, none of the groups seemed to have any marked or substantial advantage over the others on this pretest variable.

Attitude-Toward-Ecology Pretest

Tables 25 and 26 present the statistics on the students' initial attitude toward ecology, as measured by the attitude-toward-ecology pretest. These attitude scores are broken down by district, school, class, and half-class in Table 25 and by treatment and teacher in Table 26. The average attitude of half-classes ranged from 38.64 (for Half-Class 2) to 48.23 (for Half-Class 30). This is a difference of 9.59 points, more than one standard deviation. As indicated in Table 26, there were also substantial differences between treatments in initial attitude. For example, the mean for low soliciting-high reacting was 45.64, and the mean for low soliciting-low reacting was 42.91. Because of these initial differences in students' attitude toward ecology, analysis of covariance was used to investigate treatment effects on student attitude. Initial attitude was used as the covariate when attitude was the dependent variable.

TABLE 25

Means and Standard Deviations of Scores on the Attitude-toward-Ecology Pretest by District, School, Class, and Half-Class (standard deviations in parentheses)

District	School		Class		Half-Class		N
I — 43.81 (8.14)	A	43.81 (8.14)	a	40.39 (9.47)	1	41.67 (9.87)	15
					2	38.64 (9.06)	11
			b	43.48 (7.94)	3	40.20 (7.83)	10
					4	45.67 (7.48)	15
			c	47.22 (6.91)	5	46.82 (7.59)	11
					6	47.58 (6.54)	12
			d	44.56 (6.75)	7	42.92 (5.09)	12
					8	46.08 (7.89)	13
II — 43.83 (7.20)	B	45.90 (5.23)	e	45.89 (4.73)	9	45.85 (4.65)	13
					10	45.92 (4.99)	13
			f	45.92 (5.92)	11	45.25 (4.54)	12
					12	46.54 (7.09)	13
	C	46.19 (4.95)	g	47.55 (4.55)	13	47.55 (4.55)	11
			h	44.70 (5.17)	14	44.70 (5.17)	10
	D	39.00 (8.63)	i	38.71 (9.54)	15	38.71 (0.54)	14
			j	39.25 (8.05)	16	39.25 (8.05)	16
	E	44.24 (7.77)	k	41.83 (8.20)	17	41.83 (8.20)	12
	H*	45.77 (5.87)	l	45.67 (6.85)	18	45.67 (6.85)	12
	E		m	45.35 (7.46)	19	45.00 (9.27)	14
					20	45.75 (4.96)	12
	F	43.18 (7.06)	n	43.09 (6.35)	21	39.82 (5.78)	11
					22	46.36 (5.26)	11
			o	43.28 (8.03)	23	42.63 (8.37)	8
					24	43.80 (8.16)	10
III — 45.39 (7.42)	G	43.65 (7.92)	p	43.65 (7.92)	25	43.69 (8.71)	13
					26	43.60 (7.23)	10
	H	45.77 (5.87)	q	45.82 (5.52)	27	46.85 (5.03)	13
					28	44.86 (5.96)	14
	I	45.96 (8.34)	r	42.78 (10.02)	29	42.78 (10.02)	9
			s	48.23 (7.93)	30	48.23 (7.93)	13
			t	45.91 (7.81)	31	47.17 (7.27)	12
					32	44.55 (8.49)	11

*School H is in District III

TABLE 26

Means and Standard Deviations of Scores on the Attitude-toward-Ecology Pretest by Treatment and Teacher

STR X SOL X REA X TCHR					STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
TRMT	TCHR	X	S.D.	N							
HHH	1	45.85	4.65	13	HHH:						
	2	41.67	9.87	15	$\bar{X}$ = 43.23						
	3	41.83	8.20	12	SD = 8.12	HH*:	H*H:	*HH:			
	4	43.69	8.71	13	N = 53	$\bar{X}$ = 44.47	$\bar{X}$ = 44.91	$\bar{X}$ = 43.40			
HHL	1	44.86	5.96	14	HHL:	SD = 7.35	SD = 7.54	SD = 7.78			
	2	45.75	4.96	12	$\bar{X}$ = 45.69	N = 107	N = 99	N = 99			
	3	45.67	7.48	15	SD = 6.35				H**:	*H*:	**H:
	4	46.54	7.09	13	N = 54				$\bar{X}$ = 44.67	$\bar{X}$ = 44.30	$\bar{X}$ = 44.46
HLH	1	48.23	7.93	13	HLH:				SD = 7.48	SD = 7.30	SD = 7.50
	2	44.70	5.17	10	$\bar{X}$ = 46.85				N = 203	N = 202	N = 187
	3	46.36	5.26	11	SD = 6.36	HL*	H*L:	*HL:			
	4	47.58	6.54	12	N = 46	$\bar{X}$ = 44.90	$\bar{X}$ = 43.94	$\bar{X}$ = 45.16			
HLL	1	46.08	7.89	13	HLL:	SD = 7.66	SD = 7.47	SD = 6.74			
	2	44.55	8.49	11	$\bar{X}$ = 43.10	N = 96	N = 88	N = 103			
	3	39.25	8.05	16	SD = 8.35						
	4	43.80	8.16	10	N = 50						
LHH	1	38.64	9.06	11	LHH:						
	2	45.92	4.99	13	$\bar{X}$ = 43.61						
	3	43.60	7.23	10	SD = 7.45	LH*:	L*H:	*LH:			
	4	45.67	6.85	12	N = 46	$\bar{X}$ = 44.11	$\bar{X}$ = 44.44	$\bar{X}$ = 45.64			
LHL	1	45.00	9.27	14	LHL:	SD = 7.28	SD = 7.46	SD = 7.04			
	2	46.85	5.03	13	$\bar{X}$ = 44.57	N = 95	N = 104	N = 88			
	3	45.25	4.54	12	SD = 7.17				L**:	*L*:	**L:
	4	40.20	7.83	10	N = 49				$\bar{X}$ = 43.80	$\bar{X}$ = 44.21	$\bar{X}$ = 44.07
LLH	1	39.82	5.78	11	LLH:				SD = 7.56	SD = 7.78	SD = 7.56
	2	46.82	7.59	11	$\bar{X}$ = 44.31				N = 183	N = 184	N = 199
	3	42.78	10.02	9	SD = 7.57	LL*:	L*L:	*LL:			
	4	47.55	4.55	11	N = 42	$\bar{X}$ = 43.47	X = 43.66	X = 42.91			
LLL	1	38.71	9.54	14	LLL:	SD = 7.88	SD = 7.68	SD = 8.23			
	2	42.63	8.37	8	$\bar{X}$ = 42.70	N = 88	N = 95	N = 96			
	3	42.92	5.09	12	SD = 8.17						
	4	47.17	7.27	12	N = 46						

Intercorrelations among the Measures

How were the pretest and posttest measures intercorrelated? The correlation matrix for the 14 pretest and posttest variables, not all of which are experimentally independent of one another, is shown in Table 27 for the half-class as the unit of analysis, and in Table 28 for the student as the unit of analysis. In general, these coefficients have magnitudes at the levels that would be expected.

The coefficients obtained when the half-class was a unit of analysis were, for the most part, higher than those obtained when the student was the unit of analysis, as should be expected because of the greater reliability of the class means, as compared with the scores of individual students. As expected, the coefficients for the correlations between whole and part scores, such as the multiple-choice achievement test total (Variable 4 in Table 27) and the text-and-teacher-as-source: lower-order subscale (Variable 5), were extremely high. It is also noteworthy that the multiple-choice achievement test total score (Variable 4) correlated .60 with the essay achievement test total score (Variable 9). The correlation between the multiple-choice achievement test and the essay achievement test is substantial enough to indicate that the essay test, normally a difficult kind of test to make reliable, had the kind of relationship with the multiple-choice test that is typically found in studies of achievement in school subjects. It is indicative of the substantial reliability of the multiple-choice achievement test total score on the posttest (Variable 4) that it correlated .85 with the score on the same test given three weeks later (Variable 11). Similarly, the posttest score for attitude toward ecology (Variable 10) correlated .92 with the score for the same attitude measured three weeks later (Variable 17).

The confirmations of expectations that are provided by the coefficients in Table 27 lend credibility to the data yielded by these instruments. They seem to have substantial reliability and are correlated with other variables in ways that support what might be considered their construct validity. There was only a modest correlation ($\underline{r}$ = .14) between the multiple-choice achievement test total score (Variable 4 in Table 27) and the attitude-toward-ecology posttest score (Variable 10). The essay

TABLE 27

Intercorrelations of Pretests and Posttests with the Half-Class as the Unit of Analysis (N=32)

	1 VOCAB	2 ATTIT1	3 TFQ1	4 MCTOT2	5 MCLOTT2	6 MCHOTT2	7 MCLOTO2	8 MCHOTO2	9 ESTOT2	10 ATTIT2	11 MCTOT3	12 MCLOTT3	13 MCHOTT3	14 MCLOTO3	15 MCHOTO3	16 ESTOT3	17 ATTIT3	18 TFQ3
1. Vocabulary Pretest		.32	.09	.74	.64	.70	.53	.57	.44	.05	.74	.67	.74	.63	.61	.38	.12	.44
2. Attitude-toward-Ecology Pretest			.07	.32	.40	.23	.29	.12	.36	.75	.45	.47	.32	.49	.36	.34	.82	.31
3. True-False-? Knowledge-of-Ecology Pretest				.23	.04	.17	.43	.15	.12	-.02	.00	-.05	.11	.04	-.10	.34	.06	.55
4. Multiple-Choice Posttest Total					.82	.82	.84	.82	.60	.14	.85	.74	.75	.79	.77	.68	.22	.58
5. Text-and-Teacher-as-Source: Low-Ord Subscale of Mul-Ch Posttest						.53	.67	.51	.58	.26	.75	.78	.59	.76	.60	.52	.32	.51
6. Text-and-Teacher-as-Source: Hi-Ord Subscale of Mul-Ch Posttest							.55	.60	.36	.07	.77	.65	.84	.60	.64	.57	.19	.54
7. Teacher-Only-as-Source: Low-Ord Subscale of Mul-Ch Posttest								.59	.54	.20	.65	.53	.54	.72	.55	.65	.28	.50
8. Teacher-Only-as-Source: Hi-Ord Subscale of Mul-Ch Posttest									.51	.07	.63	.44	.50	.54	.74	.50	-.05	.35
9. Essay Posttest on Ecology										.25	.53	.55	.37	.55	.44	.56	.26	.38
10. Attitude-toward-Ecology Posttest											.38	.43	.25	.64	.25	.29	.92	.14
11. Multiple-Choice Retention Test Total												.90	.90	.88	.88	.61	.40	.52
12. Text-and-Teacher-as-Source: Low-Ord Subscale of Mul-Ch Reten Test													.78	.74	.72	.58	.46	.55
13. Text-and-Teacher-as-Source: Hi-Ord Subscale of Mul-Ch Reten Test														.71	.69	.46	.27	.48
14. Teacher-Only-as-Source: Low-Ord Subscale of Mul-Ch Reten Test															.73	.62	.46	.47
15. Teacher-Only-as-Source: Hi-Ord Subscale of Mul-Ch Reten Test																.53	.28	.34
16. Essay Retention Test on Ecology																	.32	.49
17. Attitude-toward-Ecology Retention Test																		.34
18. True-False-? Knowledge-of-Ecology Retention Test																		

TABLE 28

Intercorrelations of Pretests and Posttests with the Student as the Unit of Analysis (N = approximately 386)

	1 VOCAB	2 ATTIT1	3 TFQ1	4 MCTOT2	5 MCLOTT2	6 MCHOTT2	7 MCLOTO2	8 MCHOTO2	9 LOGES 2	10 ATTIT2	11 MCTOT3	12 MCLOTT3	13 MCHOTT3	14 MCLOTO3	15 MCHOTO3	16 LOGES 3	17 ATTIT3	18 TFQ3
1. Vocabulary Pretest		.19	.13	.61	.43	.53	.42	.51	.36	.14	.62	.49	.55	.43	.56	.31	.14	.45
2. Attitude-toward-Ecology Pretest			.14	.21	.14	.17	.15	.20	.18	.65	.27	.24	.19	.22	.25	.18	.61	.30
3. True-False-? Knowledge-of-Ecology Pretest				.13	-.01	.15	.15	.10	.01	.13	.10	.06	.09	.16	.02	.04	.17	.36
4. Multiple-Choice Posttest Total					.77	.81	.73	.80	.44	.20	.79	.64	.63	.62	.68	.47	.15	.52
5. Text-and-Teacher-as-Source: Low-Ord Subscale of Mul-Ch Posttest						.48	.48	.46	.35	.16	.58	.56	.45	.46	.45	.37	.20	.36
6. Text-and-Teacher-as-Source: Hi-Ord Subscale of Mul-Ch Posttest							.43	.56	.34	.15	.66	.50	.61	.47	.54	.41	.20	.42
7. Teacher-Only-as-Source: Low-Ord Subscale of Mul-Ch Posttest								.43	.33	.14	.59	.43	.44	.61	.46	.33	.16	.41
8. Teacher-Only-as-Source: Hi-Ord Subscale of Mul-Ch Posttest									.35	.17	.62	.48	.46	.41	.65	.36	.15	.42
9. Log Transformation of Essay Posttest on Ecology										.23	.47	.41	.36	.35	.42	.49	.23	.33
10. Attitude-toward-Ecology Posttest											.29	.26	.22	.26	.22	.24	.83	.27
11. Multiple-Choice Retention Test Total												.82	.83	.79	.83	.47	.33	.58
12. Text-and-Teacher-as-Source: Low-Ord Subscale of Mul-Ch Reten Test													.55	.57	.57	.41	.28	.48
13. Text-and-Teacher-as-Source: Hi-Ord Subscale of Mul-Ch Reten Test														.53	.60	.39	.27	.43
14. Teacher-Only-as-Source: Low-Ord Subscale of Mul-Ch Reten Test															.52	.35	.30	.48
15. Teacher-Only-as-Source: Hi-Ord Subscale of Mul-Ch Reten Test																.38	.23	.46
16. Log Transformation of Essay Retention Test on Ecology																	.23	.35
17. Attitude-toward-Ecology Retention Test																		.34
18. True-False-? Knowledge-of-Ecology Retention Test																		

achievement test (Variable 9) also correlated only slightly ($\underline{r}$ = .25) with the score on the attitude-toward-ecology test (Variable 10).

For the "retention" tests, given three weeks after the end of instruction, the intercorrelations shown in Table 27 had much the same kinds of values as those already noted for the posttest scores. Again, the multiple-choice (Variable 11) and the essay achievement tests of retention (Variable 16) correlated at about the level expected for such variables ($\underline{r}$ = .61). The True-False-? retention test (Variable 18) correlated .52 with the multiple-choice achievement test of retention (Variable 11).

Overall Effect of Teaching

Before examining the effects of the treatment variations, let us consider the overall effects of the teaching on student achievement and attitude. Did the students learn about ecology from the teaching as a whole? Were their attitudes toward ecology affected by the teaching? (In a subsequent section, we deal with the question of whether the teaching by a human teacher improved achievement over what would result from merely having the students read the text material.)

True-False-? Knowledge of Ecology

Table 29 shows the means and standard deviations of the 32 classes on the True-False-? test of knowledge about ecology before teaching and three weeks after teaching. The mean pretest score was 7.50 and the mean retention score was 11.38. This difference of 3.88 points was significant at the .01 level. This gain reflects the amount of knowledge that classes acquired as a result of teaching and remembered three weeks after they had been taught. Although there was no control group in the experiment, it does not seem plausible to attribute this gain to influences other than the teaching.

Attitude Toward Ecology

While knowledge about ecology increased, attitude toward ecology became less favorable during the intervals between pretest, posttest, and retention. As indicated in Table 30, the class means for attitude declined 1.39 points from pretest to posttest and 2.27 points from posttest to retention. These differences were statistically significant.

TABLE 29

Adjusted Means, Standard Deviations and t-ratio of Half-Class Means on the True-False-? Knowledge of Ecology Pretest and Retention Test (N = 32)

Variable	Mean	SD	r_{12}	t-ratio of difference between correlated means
(1) T-F-? Pretest	7.50	0.96		
			.56	19.81**
(2) T-F-? Retention	11.38	1.30	--	--

**p < .01

TABLE 30

Adjusted Means, Standard Deviations, Intercorrelations, and t-ratios of Half-Class Means on Attitude-toward-Ecology Pretest, Posttest, and Retention Test (N=32)

Variable	Mean	SD	Correlations with (2)Post	Correlations with (3)Reten.	t-ratio of differences between correlated means (2)Post	t-ratio of differences between correlated means (3)Reten.
(1) Attitude Pretest	44.25	2.72	.75	.82	-3.47**	-10.87**
(2) Attitude Posttest	42.86	3.41	-	.93	-	-9.81**
(3) Attitude Retention Test	40.59	3.34	-	-	-	-

**p < .01

It is noteworthy that similar deteriorations in attitude toward the teacher or subject matter have been found by a number of other researchers (Flanders, Morrison, & Brode, 1968; Gage, Runkel and Chatterjee, 1963; Kane & Rosenshine, 1975; Oles, 1974; Popham & Sadnavitch, 1961; Walberg, 1974). In fact, we know of only one study of teaching that found _increased_ favorability of student attitude (Gall et al., 1976). The causes of the decline in favorability have not been investigated, but Popham and Sadnavitch conjectured that a decline in interest in both physics and chemistry in high school classes reflected a kind of "reality testing." Indeed, students' initial attitude toward the subject matter might be unrealistically favorable because they have not yet explored the subject matter and are rating an abstract ideal. Their decline in favorability would thus result from greater realism as they become more familiar with the subject matter.

Treatment Effects

Now let us turn to the primary question of the experiment: Did the treatment variations have different effects on student achievement and attitude? Analysis of covariance was performed on each of the following achievement and attitude posttests and retention tests:

1. multiple-choice achievement test total and subtests, including:
   a) text-and-teacher-as-source: lower-order subscale
   b) text-and-teacher-as-source: higher-order subscale
   c) teacher-only-as-source: lower-order subscale
   d) teacher-only-as-source: higher-order subscale
2. essay achievement test
3. attitude toward ecology scale

Each analysis was performed, first, with the half-class as the unit of analysis, and, second, with the student as the unit of analysis. When the half-class was used as the unit, a three-factor analysis of covariance was performed, with structuring, soliciting, and reacting as the factors. When the student was used as the unit of analysis, teacher was included as a fourth factor. The results for the half-class as the unit of analysis will be reported first. The results for student as the unit of analysis will be considered in the section on teacher effects.

The Multiple-Choice Posttest of Achievement

The teacher-only subscales measured the information taught only by the teacher, while the text-and-teacher subscales included information that the student could have acquired by reading the furnished text material. Thus, it was expected that the treatments would have a greater effect on class achievement on the teacher-only subscales than on the text-and-teacher subscales. As we will shortly indicate, this was, in fact, the case. It was also expected that low soliciting would facilitate student performance on lower-order rather than higher-order questions on the multiple-choice achievement test. This prediction was also confirmed.

Homogeneity of regression was examined on the basis of the statistics shown in Table 20. The F value for homogeneity of regression was 2.18 with 2 and 16 degrees of freedom; the p value exceeded .05.

The results of the analysis of covariance on each of the subscales of the multiple-choice posttest are presented in Tables 31 through 34. As is indicated in Tables 31 and 32, there was a statistically significant effect for soliciting on the two teacher-only subscales. The adjusted means shown in Tables 33 and 34 reveal that the effect was in favor of low soliciting. Note that, on the teacher-only-as-source: lower-order questions subscale, the adjusted mean for the 16 classes taught with high soliciting was 4.51, and the adjusted mean for classes taught with low soliciting was 4.88 (see Table 33). Similarly, the adjusted mean for high soliciting on the teacher-only: higher-order questions subscale was 4.78, and the adjusted mean for low soliciting was 5.19 (see Table 34).

Table 35 shows that the soliciting effect on the text-and-teacher-as source: lower-order questions subscale was also statistically significant. Again, the adjusted mean for low soliciting was higher than that for high soliciting (see Table 36). As indicated in Table 37, soliciting did <u>not</u> have a statistically significant effect on the text-and-teacher-as-source: higher-order questions subscale.

In short, low soliciting improved student performance on lower-order test questions on information presented directly by the teacher, or by both text and teacher, and also on higher-order questions on information presented only by the teacher. The high soliciting treatment was not superior on any of the multiple-choice achievement subtests.

TABLE 31

Analysis of Covariance on Multiple-Choice Achievement Posttest: Lower-Order Questions with Teacher-Only-as-Source

Source	SS	df	MS	F	p
Covariate: Vocabulary	3.33	1	3.33	12.39	.002
Structuring (STR)	.70	1	.70	2.60	.117
Soliciting (SOL)	1.12	1	1.12	4.15	.051
Reacting (REA)	1.19	1	.19	.72	n.s.
STR x SOL	.04	1	.04	.13	n.s.
STR x REA	.09	1	.09	.32	n.s.
SOL x REA	.11	1	.11	.42	n.s.
STR x SOL x REA	.04	1	.04	.16	n.s.
Residual	6.18	23	.27		
Total	11.77	31	.38		

TABLE 32

Analysis of Covariance on Multiple-Choice Achievement Posttest: Higher-Order Questions with Teacher-Only-as-Source

Source	SS	df	MS	F	p
Covariate: Vocabulary	4.90	1	4.90	14.75	.001
Structuring (STR)	.01	1	.01	.04	n.s.
Soliciting (SOL)	1.33	1	1.33	4.01	.054
Reacting (REA)	.38	1	.38	1.14	.296
STR x SOL	.06	1	.06	.17	n.s.
STR x REA	1.00	1	1.00	3.00	.093
SOL x REA	.00	1	.00	.01	n.s.
STR x SOL x REA	.00	1	.00	.01	n.s.
Residual	7.63	23	.33		
Total	15.30	31	.49		

TABLE 33

Adjusted Means and Standard Deviations of Half-Class Means on Teacher-Only-as-Source: Lower-Order Questions Subscale of Multiple-Choice Posttest Showing Soliciting and Structuring Effects

	N	$\bar{X}$	SD	F
High Soliciting	16 half-classes	4.51	0.51	4.15*
Low Soliciting	16 half-classes	4.88	0.48	
	N	$\bar{X}$	SD	F
High Structuring	16 half-classes	4.83	0.60	2.60†
Low Structuring	16 half-classes	4.55	0.40	

†p = .117
*p = .051

TABLE 34

Adjusted Means and Standard Deviations of Half-Class Means on Teacher-Only-as-Source: Higher-Order Questions Subscale of Multiple-Choice Achievement Posttest Showing Soliciting Effect and Structuring x Reacting Interaction

	N	$\bar{X}$	SD	F
High Soliciting	16 half-classes	4.78	0.47	4.01*
Low Soliciting	16 half-classes	5.19	0.62	

		Structuring: High	Structuring: Low	F
Reacting	High	$\bar{X}$ = 4.95 SD = 0.53 N = 8 half-classes	$\bar{X}$ = 5.24 SD = 0.69 N = 8 half-classes	3.00†
	Low	$\bar{X}$ = 5.06 SD = 0.39 N = 8 half-classes	$\bar{X}$ = 4.69 SD = 0.64 N = 8 half-classes	

†p = .093
*p = .054

TABLE 35

Analysis of Covariance on Multiple-Choice Achievement Posttest: Lower-Order Questions with Text-and-Teacher as Source

Source	SS	df	MS	F	p
Covariate: Vocabulary	6.15	1	6.15	29.41	.001
Structuring: (STR)	.04	1	.04	.19	n.s.
Soliciting: (SOL)	2.16	1	2.16	10.31	.004
Reacting: (REA)	.04	1	.04	.18	n.s.
STR x SOL	.02	1	.02	.10	n.s.
STR x REA	1.12	1	1.12	5.36	.028
SOL x REA	.12	1	.12	.59	n.s.
STR x SOL x REA	.33	1	.33	1.59	.218
Residual	4.81	23	.21		
Total	14.91	31	.48		

TABLE 36

Adjusted Means and Standard Deviations of Half-Class Means on Text-and-Teacher-as-Source: Lower-Order Questions Subscale of Multiple-Choice Posttest Showing Soliciting Effect and Structuring x Reacting Interaction

	N	$\bar{X}$	SD	F
High Soliciting	16 half-classes	5.11	0.42	10.31*
Low Soliciting	16 half-classes	5.63	0.52	

		Structuring: High	Structuring: Low	F
Reacting	High	$\bar{X}$ = 5.26 SD = 0.57 N = 8 half-classes	$\bar{X}$ = 5.56 SD = 0.57 N = 8 half-classes	5.36†
	Low	$\bar{X}$ = 5.55 SD = 0.52 N = 8 half-classes	$\bar{X}$ = 5.12 SD = 0.42 N = 8 half-classes	

†p = .030
*p = .004

TABLE 37

Analysis of Covariance on Multiple-Choice Achievement Posttest
Higher-Order Questions with Text-and-Teacher as Source

Source	SS	df	MS	F	p
Covariate: Vocabulary	8.14	1	8.14	23.14	.001
Structuring: (STR)	.01	1	.01	.04	n.s.
Soliciting: (SOL)	.04	1	.04	.12	n.s.
Reacting: (REA)	.15	1	.15	.42	n.s.
STR x SOL	.11	1	.11	.32	n.s.
STR x REA	.05	1	.05	.14	n.s.
SOL x REA	.08	1	.08	.22	n.s.
STR x SOL x REA	.15	1	.15	.43	n.s.
Residual	8.09	23	.35		
Total	16.80	31	.54		

The findings on soliciting are consistent with the results of an experiment by Gall and others (1976). They found that student groups that received a 50 percent higher-order-questioning treatment had considerably lower average achievement than a group that received a 25 percent higher-order-questioning and 75 percent lower-order questioning treatment. The present study, using 15 percent and 60 percent higher-order questioning in the low- and high-soliciting treatments, respectively, confirms the difference between the 25 and 50 percent higher-order-questioning treatments used by Gall and others (1976).

The present study also yielded some indication of a structuring effect on immediate achievement. Table 31 reveals that the main effect of structuring on the teacher-only: lower-order questions subscale, approached significance at the .10 level. The adjusted means in Table 33 show that this effect was in favor of high structuring. When Tables 32 and 35 are inspected, one can see that the structuring effect appeared in the form of a structuring x reacting interaction on the teacher-only: higher-order questions subscale and the teacher-and-text: lower-order questions subscale. When this interaction is examined, one finds that the low structuring with low reacting was the worst treatment (see Tables 34 and 36).*

In summary, high rather than low structuring improved student achievement on several subscales of the multiple-choice posttest. Also, low soliciting was more effective than high soliciting.

But which of the eight treatment variations was best for student achievement on the multiple-choice test? Table 38 presents the adjusted half-class means for the eight treatment variations on the teacher-only-as-source subscales of the multiple-choice achievement posttest. Half-classes receiving the HLH (high structuring-low soliciting-high reacting) treatment had the highest mean ($\bar{X} = 5.16$) on the teacher-only: lower-order subscale and on the total teacher-only subscale ($\bar{X} = 10.39$). Logically, it should follow that the least effective treatment was the opposite of HLH--namely, LHL (low structuring-high soliciting-low reacting). This was indeed the case. The average achievement on the teacher-only-as-source subscales for classes receiving the LHL treatment was 4.29 for lower-order questions and 4.52 for higher-order questions. The difference between the best treatment (HLH) and the worst treatment (LHL) in total achievement on the teacher-only subscales was 1.57 points--a difference of between 1.0 and 1.5 standard deviations.

The 1.57-point difference reflects the difference in achievement between HLH and LHL classes after initial differences in scholastic ability (vocabulary) have been removed. If one doubted the adequacy of analysis of covariance in adjusting for initial differences, one could argue that the HLH half-classes had the highest average achievement because they had the highest mean vocabulary (see Table 38). But this argument breaks down for LHL classes because they had the third highest mean vocabulary, despite having the lowest average achievement. Thus, one can be fairly well assured that the difference in achievement between HLH and LHL was not due to a difference in the initial ability of the

*In a subsequent section the role of students' perceptions in mediating these effects is examined by means of path analysis.

TABLE 38

Means of Eight Treatment Variations: Means and Standard Deviations of Vocabulary Half-Class Means and Adjusted Multiple-Choice Achievement Posttest Half-Class Means on Teacher-Only-as-Source Lower-Order and Higher-Order Questions

Treatment Variations in terms of Structuring, Soliciting, and Reacting	Number of Half-Classes	Vocabulary		Adjusted Teacher-Only-as-Source Scores					
				Lower-Order		Higher-Order		Total	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
HHH	4	22.13	1.81	4.71	0.71	4.68	0.24	9.40	0.80
HHL	4	21.63	1.76	4.65	0.53	4.84	0.43	9.44	0.33
HLH	4	23.63	1.13	5.16	0.76	5.22	0.64	10.39	1.37
HLL	4	19.98	2.26	4.82	0.47	5.28	0.20	10.11	0.53
LHH	4	19.18	1.92	4.37	0.52	5.08	0.33	9.41	0.77
LHL	4	21.88	3.17	4.29	0.27	4.52	0.74	8.82	1.00
LLH	4	20.03	3.84	4.83	0.34	5.39	0.97	10.25	1.23
LLL	4	21.45	1.92	4.70	0.25	4.87	0.56	9.59	0.45

students receiving these treatments. As should be the case mathematically, the correlation between the eight treatment groups' mean vocabulary and adjusted mean multiple-choice achievement test scores on the teacher-only items was zero.

Do the results for total multiple-choice achievement on the two teacher-only-as-source subscales show that the effects of structuring, soliciting, and reacting were additive or interactive? To examine the question of additivity, we can compare (a) the sum of the main effects of structuring, soliciting, and reacting, with (b) the difference between the effects of the HLH and LHL treatments. The difference between high structuring and low structuring was .31 points in favor of high structuring. The difference between high soliciting and low soliciting was .81 points in favor of low soliciting. The difference between high reacting and low reacting was .37 points in favor of high reacting. The sum of these three main effects was 1.49 points. This value may be compared with the 1.57 point difference between HLH and LHL treatment variations. This comparison indicates that the effects of teacher behavior on posttest achievement were primarily additive with only .08 points (1.57 minus 1.49) attributable to interaction effects of the three treatments.

The effects of the treatments on the text-and-teacher-as-source achievement test items should not be as striking. Logically, achievement on these items was affected by both the text, which was the same for all students, and the eight treatments that varied from one group of students to another. Thus the treatment effects should be attenuated by the uniformity of the text effect.

The adjusted means of the eight treatment groups on the text-and-teacher-as-source items are shown in Table 39. It is evident that the most effective treatment is now LLH (adjusted mean for total text-and-teacher-as-source items = 11.37), while the least effective treatment on these items is still LHL (adjusted mean = 10.20). Thus the logically opposite treatments no longer yield the empirical extremes when text-and-teacher-as-source items serve as the criterion of effectiveness.

TABLE 39

Means of Eight Treatment Variations: Means and Standard Deviations of Vocabulary Half-Class Means and Adjusted Multiple-Choice Achievement Test Half-Class Means on Text-and-Teacher-as-Source Lower-Order and Higher-Order Questions

Treatment Variations in terms of Structuring, Soliciting, and Reacting	Number of Half-Classes	Vocabulary		Adjusted Text-and-Teacher-as-Source Scores: Lower-Order		Higher-Order		Total	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
HHH	4	22.13	1.81	5.04	0.62	5.34	0.59	10.36	0.67
HHL	4	21.63	1.76	5.31	0.45	5.32	0.24	10.62	0.50
HLH	4	23.63	1.13	5.47	0.49	5.58	0.67	11.05	0.93
HLL	4	19.98	2.26	5.80	0.52	5.46	0.20	11.26	0.59
LHH	4	19.18	1.92	5.09	0.30	5.62	0.97	10.72	1.19
LHL	4	21.88	3.17	5.01	0.35	5.19	0.21	10.20	0.56
LLH	4	20.03	3.84	6.02	0.30	5.35	0.83	11.37	0.56
LLL	4	21.45	1.92	5.24	0.51	5.38	0.37	10.57	0.81

The separate main effects on the text-and-teacher-as-source total scores equal .11 for structuring, .58 for soliciting, and .21 for reacting. The sum of these main effects is .90. The difference between the adjusted means on the same items for the HLH and the LHL treatments (the latter being again the least effective treatment on these items) is .85. Again the sum of the main effects (.90) closely approximates the difference between the effects when all three treatments are varied (.85). Here again the evidence suggests additive rather than interactive effects of the three treatments. When the adjusted mean of LLH, the most effective treatment (11.37), is compared with that of HHL, its logical opposite (10.62), the difference is .75. This value should be compared with the sum of the main effects, which are now -.11 for structuring, .58 for soliciting, and .21 for reacting. Thus the sum of the main effects is now .68, which is less than the difference of .75 when all three treatments were varied. The difference between .75 and .68 now suggests that the slight interactive effect operates so as to increase the effect when all three treatments are manipulated over that obtained when their separate effects are summed.

Essay and Attitude-Toward-Ecology Posttests

How did the treatments affect essay test performance and attitude-toward-ecology? The results of the analysis of covariance on the essay posttest are presented in Table 40. As can be seen, the treatment variations had no significant effects on mean half-class achievement on the essay posttest.

What about the effects of the treatments on attitudes toward the subject matter? Did students taught by one treatment or another emerge with significantly more or less favorable attitudes toward ecology? Here, analyses of covariance were performed with the attitude-toward-ecology pretest score as the covariate. Table 41 presents the results. Again, there were no significant treatment effects.

Multiple-Choice Retention Test

Did the treatments affect student retention of the information on the multiple-choice test given three weeks later? The argument and evidence presented above should lead us to expect to find effects only on

TABLE 40

Analysis of Covariance on Essay Achievement Posttest with Half-Class Means as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Vocabulary	3.63	1	3.63	6.33	.018
Structuring: (STR)	.37	1	.37	.65	n.s.
Soliciting: (SOL)	.02	1	.02	.03	n.s.
Reacting: (REA)	.38	1	.38	.66	n.s.
STR x SOL	.00	1	.00	.00	n.s.
STR x REA	.80	1	.80	1.34	.25
SOL x REA	.00	1	.00	.01	n.s.
STR x SOL x REA	.38	1	.38	.66	n.s.
Residual	13.21	23	.58		
Total	18.82	31	.61		

TABLE 41

Analysis of Covariance on Attitude-toward-Ecology Posttest with the Half-Class as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Attitude-Toward Ecology Pretest	202.43	1	202.43	35.44	.001
Structuring: (STR)	2.78	1	2.78	.49	n.s.
Soliciting: (SOL)	.23	1	.23	.04	n.s.
Reacting: (REA)	1.91	1	1.91	.34	n.s.
STR x SOL	11.43	1	11.43	2.00	.168
STR x REA	6.16	1	6.16	1.08	.311
SOL x REA	3.29	1	3.29	.58	n.s.
STR x SOL x REA	.94	1	.94	.17	n.s.
Residual	131.37	23	5.71		
Total	360.08	31	11.62		

the lower-order teacher-only subscale rather than on the other three subscales. As Table 42 indicates, this subscale showed a structuring effect, significant at the .01 level; the soliciting effect was significant at the .07 level, and the reacting effect was significant at the .10 level. Table 43 shows that half-classes that received high structuring retained more information about ecology ($\bar{X}$ = 4.37) than those that received low structuring ($\bar{X}$ = 3.91). As was true on the immediate posttest of achievement, classes benefited more from low soliciting ($\bar{X}$ = 4.30) than high soliciting ($\bar{X}$ = 3.98). Finally, high reacting yielded higher retention ($\bar{X}$ = 4.29) than did low reacting ($\bar{X}$ = 3.99). Thus, the differences on the retention test were in the same direction as those on the posttest, and the likelihood that these differences on the retention test could be attributable to chance was less than that for the posttest differences.

In contrast, the other retention test subscales showed no significant main effects of treatments (see Tables 44 through 46). Nonetheless, as was the case for posttest achievement, the structuring-by-reacting interaction significantly affected the lower-order text-and-teacher subscale (p = .04) and the higher-order teacher-only subscale (p = .06). The adjusted means for this interaction shown in Tables 47 and 48 indicated that retention was lowest in the low structuring-low reacting treatment. The structuring-by-reacting effect thus influenced retention in the same direction as it influenced posttest achievement.

The significant effect of structuring on retention is consistent with psychological models of memory and cognition. Structuring should help students organize the information so that it can be more easily retrieved when needed. Structuring would probably become more important as the interval between storage and retrieval increased. Thus, one would predict that, if any one of the three treatments were to affect retention of the material, structuring would be the one.

How did the eight treatment variations compare in terms of retention on the teacher-only-as-source subtests of the multiple-choice achievement test? Table 49 reveals that the highest retention was attained by half-classes receiving the LLH (low structuring-low soliciting-high reacting) treatment and the lowest retention by classes receiving the LHL (low

TABLE 42

Analysis of Covariance on Multiple-Choice Retention Test Lower-Order Questions with Teacher-Only-as-Source

Source	SS	df	MS	F	p
Covariate: Vocabulary	6.49	1	6.49	27.09	.001
Structuring: (STR)	1.81	1	1.81	7.55	.011
Soliciting: (SOL)	.82	1	.82	3.43	.074
Reacting: (REA)	.69	1	.69	2.35	.101
STR x SOL	.48	1	.48	1.99	.169
STR x REA	.36	1	.36	1.50	.232
SOL x REA	.12	1	.12	.52	n.s.
STR x SOL x REA	.00	1	.00	.01	n.s.
Residual	5.51	23	.24		
Total	16.34	31	.53		

TABLE 43

Adjusted Means and Standard Deviations of Half-Class Means on Teacher-Only-as-Source: Lower-Order Questions Subscale of Multiple-Choice Retention Test Showing Soliciting, Structuring, and Reacting Effects

	N	$\bar{X}$	SD	F
High Structuring	16 half-classes	4.37	0.43	7.55[a]
Low Structuring	16 half-classes	3.91	0.60	
	N	$\bar{X}$	SD	F
High Soliciting	16 half-classes	3.98	0.58	3.43[b]
Low Soliciting	16 half-classes	4.30	0.51	
	N	$\bar{X}$	SD	F
High Reacting	16 half-classes	4.29	0.44	2.86[c]
Low Reacting	16 half-classes	3.99	0.64	

[a] p = .011
[b] p = .074
[c] p = .101

TABLE 44

Analysis of Covariance on Multiple-Choice Retention Test:
Higher-Order Questions with Teacher-Only-as-Source

Source	SS	df	MS	F	p
Covariate: Vocabulary	7.94	1	7.94	19.14	.001
Structuring: (STR)	.08	1	.08	.18	n.s.
Soliciting: (SOL)	.66	1	.66	1.58	.219
Reacting: (REA)	.91	1	.91	2.18	.150
STR x SOL	.00	1	.00	.01	n.s.
STR x REA	1.56	1	1.56	3.77	.062
SOL x REA	.28	1	.28	.67	n.s.
STR x SOL x REA	.16	1	.16	.39	n.s.
Residual	9.54	23	.42		
Total	21.29	31	.69		

TABLE 45

Analysis of Covariance on Multiple-Choice Retention Test:
Lower-Order Questions with Text-and-Teacher-as-Source

Source	SS	df	MS	F	p
Covariate: Vocabulary	8.52	1	8.52	27.20	.001
Structuring: (STR)	.00	1	.00	.01	n.s.
Soliciting: (SOL)	.57	1	.57	1.82	.188
Reacting: (REA)	.26	1	.26	.83	n.s.
STR x SOL	.38	1	.38	1.20	.285
STR x REA	1.47	1	1.47	4.69	.039
SOL x REA	.16	1	.16	.51	n.s.
STR x SOL x REA	.19	1	.19	.61	n.s.
Residual	7.21	23	.31		
Total	18.87	31	.61		

TABLE 46

Analysis of Covariance on Multiple-Choice Retention Test: Higher-Order Questions with Text-and-Teacher-as-Source

Source	SS	df	MS	F	p
Covariate: Vocabulary	14.76	1	14.76	35.18	.001
Structuring: (STR)	.36	1	.36	.35	n.s.
Soliciting: (SOL)	.17	1	.17	.40	n.s.
Reacting: (REA)	.45	1	.45	1.06	.315
STR x SOL	.02	1	.02	.06	n.s.
STR x REA	.57	1	.57	1.35	.256
SOL x REA	.01	1	.01	1.02	n.s.
STR x SOL x REA	.41	1	.41	.97	n.s.
Residual	9.65	23	.42		
Total	26.37	31	.85		

TABLE 47

Adjusted Means and Standard Deviations of Half-Class Means on Text-and-Teacher-as-Source: Lower-Order Questions Subscale of Multiple-Choice Retention Test Showing Structuring x Reacting Interaction

		Structuring: High	Structuring: Low	F
Reacting	High	$\bar{X}$ = 4.71 SD = 0.70 N = 8 half-classes	$\bar{X}$ = 5.09 SD = 0.44 N = 8 half-classes	4.69[a]
	Low	$\bar{X}$ = 4.93 SD = 0.54 N = 8 half-classes	$\bar{X}$ = 4.51 SD = 0.52 N = 8 half-classes	

[a]p = .039

TABLE 48

Adjusted Means and Standard Deviations of Half-Class Means on Teacher-Only-as-Source: Higher-Order Questions Subscale of Multiple-Choice Retention Test Showing Structuring x Reacting Interaction

		Structuring		
		High	Low	F
Reacting	High	$\bar{X}$ = 4.82 SD = 0.69 N = 8 half-classes	$\bar{X}$ = 5.16 SD = 0.76 N = 8 half classes	3.77[a]
	Low	$\bar{X}$ = 4.91 SD = 0.53 N = 8 half-classes	$\bar{X}$ = 4.39 SD = 0.47 N = 8 half-classes	

[a] $p = .062$

structuring-high soliciting-low reacting). The HLH (high structuring-low soliciting-high reacting) treatment, which was the most effective of the eight treatment variations on the teacher-only items of the achievement posttest, produced the second highest average retention. We saw in Table 42 that structuring, soliciting, and reacting had significant main effects on the teacher-only-as-source: lower-order questions subscale of the multiple-choice retention test. These effects favored high structuring, low soliciting, and high reacting. But Table 49 indicates that, when the effects of the combined treatments are examined, the LLH (low structuring-low soliciting-high reacting) treatment had slightly better effects than the HLH (high structuring-low soliciting-high reacting) treatment. These findings suggest that the effects of the three clusters of teacher behaviors on retention were not strictly additive, but also interactive. Indeed, as Tables 12 and 13 in Appendix E show, the average retention on the total teacher-only-as-source subscale (summing the lower- and higher-order subscales) of high-structuring half-classes was 0.56 points greater than that of low-structuring half-classes; that of low-soliciting half-classes was 0.60 points higher than that of high-soliciting half-classes; and that of high-reacting half-classes was 0.64 points higher than that of low-reacting half-classes. The sum of the main effects was 1.80 points. But the difference between total achievement of HLH and LHL in Table 49 was 1.94. These results suggest that the effects of teacher behavior were not interactive (1.94 - 1.80 = 0.14 points) as well as additive.

TABLE 49

Means of Eight Treatment Variations on Multiple-Choice Retention Test: Means and Standard Deviations of Vocabulary Half-Class Means and Adjusted Half-Class Means on Teacher-Only-as-Source Lower-Order and Higher-Order Questions

Treatment Variations in terms of Structuring, Soliciting, and Reacting	Number of Half-Classes	Vocabulary		Adjusted Teacher-Only-as-Source Scores on Retention Test: Lower-Order		Higher-Order		Total	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
HHH	4	22.13	1.81	4.29	0.49	4.49	0.65	8.79	1.02
HHL	4	21.63	1.76	4.38	0.47	4.97	0.58	9.38	1.03
HLH	4	23.63	1.13	4.49	0.26	5.14	0.65	9.62	0.76
HLL	4	19.98	2.26	4.33	0.60	4.86	0.56	9.20	1.06
LHH	4	19.18	1.92	3.85	0.39	4.97	0.87	8.83	1.23
LHL	4	21.88	3.17	3.41	0.54	4.27	0.49	7.68	0.52
LLH	4	20.03	3.84	4.52	0.87	5.35	0.69	9.86	0.96
LLL	4	21.45	1.92	3.86	0.61	4.51	0.49	8.37	0.96

The adjusted means for the eight treatments on the text-and-teacher-as-source items of the multiple-choice achievement retention test are shown in Table 50. Again, the most effective of the eight treatments was HLH, and the least effective was LHL, regardless of whether the nine lower-order, the nine higher-order, or all 18 questions of this kind are considered. The difference between the adjusted total mean for the HLH treatment (10.55) and that for the LHL treatment (9.14) was 1.41 points. As is evident in Tables 10 and 11 in Appendix E the sum of the differences between adjusted means for structuring (.22), soliciting (.40, in favor of low soliciting), and reacting (.42) equalled 1.04. Thus, the sum of the three main effects is somewhat less than that of the three treatment variables acting together and simultaneously, as occurs when HLH and LHL are compared. Thus, although the structuring x soliciting x reacting interaction effect was not statistically significant, the data provide some indication that an interaction effect, perhaps attributable to chance, may have occurred.

The results for multiple-choice achievement and retention also indicate that the sensitivity of achievement to treatment effects increases as the achievement measure becomes more relevant to the treatment. Thus, the results for the teacher-only and text-and-teacher subtests support the proposition that the proper measure of teaching effectiveness is acquisition and retention of information and comprehension that were available only through the teacher and could not be learned from any other source, such as text material.

Essay and Attitude-Toward-Ecology Retention Tests

The results of the analysis of covariance of half-class means on essay retention are presented in Table 51. There was a significant main effect for reacting. Table 52 shows that high reacting produced higher essay retention test scores. We attribute this effect to the increased test-taking motivation of students who had received the high-reacting treatment rather than the low-reacting treatment. In other words, high reacting had a greater effect on student achievement as the task difficulty increased. The essay test was a very difficult test. The students had to put their own ideas on paper--a task that is often

TABLE 50

Means of Eight Treatment Variations on Multiple-Choice Retention Test: Means and Standard Deviations of Vocabulary Half-Class Means and Adjusted Half-Class Means on Text-and-Teacher-as-Source Lower-Order and Higher-Order Questions

Treatment Variations in terms of Structuring, Soliciting, and Reacting	Number of Half-Classes	Vocabulary		Adjusted Text-and-Teacher-as-Source Scores on Retention Test: Lower-Order		Higher-Order		Total	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
HHH	4	22.13	1.81	4.29	0.35	5.05	0.72	9.35	0.65
HHL	4	21.63	1.76	4.87	0.53	5.29	0.85	10.16	1.36
HLH	4	23.63	1.13	5.12	0.76	5.46	0.38	10.55	1.07
HLL	4	19.98	2.26	4.99	0.62	5.27	0.37	10.28	0.77
LHH	4	19.18	1.92	5.06	0.38	5.40	0.97	10.44	1.27
LHL	4	21.88	3.17	4.49	0.65	4.65	0.48	9.14	1.09
LLH	4	20.03	3.84	5.13	0.56	5.24	0.72	10.36	1.21
LLL	4	21.45	1.92	4.53	0.46	4.99	0.14	9.50	0.50

difficult. Since students did not receive feedback on their performance on the essay posttest, their performance on essay retention probably was largely a function of their motivation to attempt answers to the same difficult questions that they had answered previously. This task persistence was apparently facilitated by the high-reacting treatments.

TABLE 51

Analysis of Covariance on Essay Retention Test with Half-Class Means as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Vocabulary	2.55	1	2.55	5.22	.030
Structuring: (STR)	.03	1	.03	.06	n.s.
Soliciting: (SOL)	.60	1	.60	1.22	.280
Reacting: (REA)	3.06	1	3.06	6.25	.019
STR x SOL	.21	1	.21	.43	n.s.
STR x REA	.22	1	.22	.45	n.s.
SOL x REA	.00	1	.00	.00	n.s.
STR x SOL x REA	.14	1	.14	.28	n.s.
Residual	11.25	23	.49		
Total	18.05	31	.58		

TABLE 52

Adjusted Means and Standard Deviations of Half-Class Means on Essay Retention Test Showing Reacting Effect

	N	$\bar{X}$	SD	F
High Reacting	16 half-classes	1.34	0.71	6.25[a]
Low Reacting	16 half-classes	0.72	0.57	

[a] $p = .019$

When analysis of covariance was performed on attitude retention, there were no significant treatment effects (see Table 53). This result confirms the results already described for the attitude posttest. Apparently nothing occurred in the three-week interval between posttest and retention test to change the effects of the treatments on attitude toward ecology. Nonetheless, as is indicated in Table 30, attitude became less favorable during this period.

TABLE 53

Analysis of Covariance on Attitude-toward-Ecology Retention Test with the Half-Class as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Attitude-Toward Ecology Pretest	234.00	1	234.00	52.14	.001
Structuring: (STR)	2.45	1	2.45	.55	n.s.
Soliciting: (SOL)	.12	1	.12	.03	n.s.
Reacting: (REA)	.01	1	.01	.00	n.s.
STR x SOL	1.90	1	1.90	.42	n.s.
STR x REA	1.71	1	1.71	.38	n.s.
SOL x REA	1.16	1	1.16	.26	n.s.
STR x SOL x REA	1.72	1	1.72	.38	n.s.
Residual	103.40	23	4.50		
Total	346.73	31	11.19		

Teacher Effects

Having described the effects of treatments on student achievement and attitude, we now consider the question of teacher effects. Although the teachers were trained to behave in accordance with the eight factorially designed treatments, it was conceivable that the teachers would have different effects as a result of differences in the many dimensions of their behavioral style and personal presence that were of necessity left uncontrolled by their training. To investigate this possibility, analyses of covariance were performed in which the teachers were included as a factor along with the three factorially designed treatment factors. These four-factor analyses of covariance (one teacher factor and three treatment factors) were performed with the dependent variables that have already been described--the multiple-choice and essay achievement tests and the attitude-toward-ecology inventory, given one day after, and three weeks after, the end of the teaching. All of the four-factor analyses of covariance were of necessity performed with the student as the unit of analysis because using the class as the unit of analysis would have made each cell have only one case, with no basis for estimating within-cell error variance.

The Multiple-Choice Posttest of Achievement

Despite the rigorous control of content and teacher behavior, were there still noticeable differences in the effectiveness of individual teachers as measured by the subscales of the multiple-choice posttest of achievement? The answer is "Yes." As shown in Table 54, a significant main effect for teacher appeared on the teacher-only-as-source: lower-order questions subscale of the multiple-choice posttest of achievement. The adjusted means for the four teachers are presented in Table 55, along with the mean vocabulary test scores of each teacher's students. The highest adjusted mean achievement was attained by students of Teacher 1, and the lowest was obtained by students of Teacher 3. It is evident in Table 55 that the differences in the adjusted achievement posttest means of the four teachers' students cannot be attributed to the initial differences between the four sets of students in scholastic aptitude (vocabulary test score).

In view of the relatively well-controlled nature of the classroom interaction, the teacher effects were probably due to personal variations unique to each teacher and unrelated to the teaching behaviors manipulated in this study. The four teachers were not studied for variations in their behavior while teaching that were not components of the composite variables of structuring, soliciting, and reacting. Hence, the nature of such differences between them could not be determined in this study. The results of this study suggest that future research should systematically investigate the effects of other behavioral differences between teachers, even in experiments focused on the effects of manipulated teacher behavior and teacher effects.

One should also note in Table 54 that, as was the case for the results with the class as the unit of analysis (shown in Table 31), there was a significant soliciting effect, and the structuring effect approached significance at the .05 level.

TABLE 54

Analysis of Covariance on Multiple-Choice Achievement Posttest: Lower-Order Questions with Teacher-Only-as-Source and Student as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Vocabulary	192.52	1	192.52	86.30	.001
Structuring: (STR)	10.03	1	10.03	6.33	.086
Soliciting: (SOL)	14.10	1	14.10	12.39	.037
Reacting: (REA)	2.58	1	2.58	.58	n.s.
Teacher: (TCHR)	22.83	3	7.61	3.41	.018
STR x SOL	.35	1	.35	.66	n.s.
STR x REA	.90	1	.90	.21	n.s.
STR x TCHR	4.75	3	1.58	.71	n.s.
SOL x REA	.84	1	.84	.33	n.s.
SOL x TCHR	3.41	3	1.14	.51	n.s.
REA x TCHR	13.39	3	4.46	2.00	.112
STR x SOL x REA	.41	1	.41	.17	n.s.
STR x SOL x TCHR	1.58	3	.53	.24	n.s.
STR x REA x TCHR	12.90	3	4.30	1.93	.123
SOL x REA x TCHR	7.59	3	2.53	1.18	.335
STR x SOL x REA x TCHR	7.06	3	2.35	1.06	.369
Residual	785.23	352	2.23		
Total	1080.20	384	2.81		

TABLE 55

Adjusted Means and Standard Deviations of Student Scores on Teacher-Only-as-Source: Lower-Order Questions Subscale of Multiple-Choice Posttest Showing Main Effect of Teacher

		Adjusted Posttest Scores on Teacher-Only-as-Source: Lower-Order Questions		Vocabulary	
	N	$\bar{X}$	SD	$\bar{X}$	SD
Teacher 1	103	5.02	1.46	20.49	5.91
Teacher 2	93	4.71	1.30	21.80	5.00
Teacher 3	97	4.34	1.68	21.14	5.68
Teacher 4	93	4.72	1.55	21.59	5.30

The teacher-only-as-source: higher-order questions subscale of the multiple-choice posttest showed no main effects for teacher, but there were nearly significant teacher x treatment interactions. Table 56 indicates that the structuring x teacher interaction was significant at the .07 level; the soliciting x teacher interaction reached significance at the .10 level; and the reacting x teacher interaction was significant at the .11 level. The means for these interactions are shown in Table 57. These results indicate that the effect of the treatment depended on the teacher. High structuring benefited students if the structuring was done by Teacher 3 or Teacher 4. Low structuring was best for students of Teacher 2. Similarly, low soliciting improved achievement of students of Teachers 1, 2 or 3; high soliciting increased achievement of Teacher 4's students. Finally, use of high reacting by Teachers 1 and 3 increased student achievement, and low reacting by Teachers 2 and 4 increased achievement.

TABLE 56

Analysis of Covariance on Multiple-Choice Achievement Posttest: Higher-Order Questions with Teacher-Only-as-Source and Student as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Vocabulary	405.06	1	405.06	140.56	.001
Structuring: (STR)	.10	1	.10	.02	n.s.
Soliciting: (SOL)	17.90	1	17.90	2.97	.183
Reacting: (REA)	4.48	1	4.48	.78	n.s.
Teacher: (TCHR)	10.65	3	3.55	1.23	.297
STR x SOL	.55	1	.54	.18	n.s.
STR x REA	12.69	1	12.69	17.98	.022
STR x TCHR	20.31	3	6.77	2.35	.071
SOL x REA	.01	1	.01	.04	n.s.
SOL x TCHR	18.08	3	6.03	2.09	.100
REA x TCHR	17.13	3	5.71	1.98	.115
STR x SOL x REA	.05	1	.05	.03	n.s.
STR x SOL x TCHR	9.28	3	3.09	1.08	.361
STR x REA x TCHR	2.12	3	.71	.24	n.s.
SOL x REA x TCHR	.72	3	.24	.08	n.s.
STR x SOL x REA x TCHR	5.31	3	1.77	.62	n.s.
Residual	1014.37	352	2.88		
Total	1541.29	384	4.01		

TABLE 57

Adjusted Means and Standard Deviations of Student Scores on Teacher-Only-as-Source: Higher-Order Questions Subscale of Multiple-Choice Posttest Showing Teacher x Treatment Interactions

		Teacher 1	Teacher 2	Teacher 3	Teacher 4
Structuring	High	$\bar{X}$ = 5.03	$\bar{X}$ = 4.82	$\bar{X}$ = 4.84	$\bar{X}$ = 5.20
		SD = 1.70	SD = 1.52	SD = 1.65	SD = 1.42
		N = 53	N = 48	N = 54	N = 48
	Low	$\bar{X}$ = 5.09	$\bar{X}$ = 5.51	$\bar{X}$ = 4.56	$\bar{X}$ = 4.58
		SD = 2.09	SD = 1.61	SD = 1.71	SD = 1.89
		N = 50	N = 45	N = 43	N = 45
Soliciting	High	$\bar{X}$ = 4.71	$\bar{X}$ = 4.91	$\bar{X}$ = 4.33	$\bar{X}$ = 5.08
		SD = 1.88	SD = 1.57	SD = 1.68	SD = 1.78
		N = 52	N = 53	N = 49	N = 48
	Low	$\bar{X}$ = 5.41	$\bar{X}$ = 5.47	$\bar{X}$ = 5.11	$\bar{X}$ = 4.71
		SD = 1.85	SD = 1.58	SD = 1.59	SD = 1.57
		N = 51	N = 40	N = 48	N = 45
Reacting	High	$\bar{X}$ = 5.48	$\bar{X}$ = 5.08	$\bar{X}$ = 4.92	$\bar{X}$ = 4.80
		SD = 1.70	SD = 1.71	SD = 1.64	SD = 1.72
		N = 48	N = 49	N = 42	N = 48
	Low	$\bar{X}$ = 4.69	$\bar{X}$ = 5.24	$\bar{X}$ = 4.56	$\bar{X}$ = 5.01
		SD = 1.98	SD = 1.46	SD = 1.69	SD = 1.67
		N = 55	N = 44	N = 55	N = 45

The reacting x teacher interaction was also significant on the teacher-and-text-as-source: lower-order questions subscale (see Table 59). The means in Table 59 demonstrate that, in contrast to the results for teacher-only items described above, students benefited from high reacting by Teachers 1 and 4 and low reacting by Teachers 2 and 3. There was also a significant main effect for soliciting, as was the case for the results with the class as the unit of analysis in Table 35.

TABLE 58

Analysis of Covariance on Multiple-Choice Achievement Posttest: Lower-Order Questions with Text-and-Teacher-as-Source and Student as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Vocabulary	228.16	1	228.16	90.56	.001
Structuring: (STR)	1.08	1	1.08	.53	n.s.
Soliciting: (SOL)	27.54	1	27.54	13.56	.033
Reacting: (REA)	.30	1	.30	.04	n.s.
Teacher: (TCHR)	6.85	3	2.28	.91	n.s.
STR x SOL	.29	1	.29	.17	n.s.
STR x REA	6.11	1	6.11	1.55	.302
STR x TCHR	6.08	3	2.03	.80	n.s.
SOL x REA	3.22	1	3.22	1.22	.350
SOL x TCHR	6.09	3	2.03	.80	n.s.
REA x TCHR	22.78	3	7.59	3.01	.029
STR x SOL x REA	2.55	1	2.55	14.64	.030
STR x SOL x TCHR	5.20	3	1.73	.69	n.s.
STR x REA x TCHR	11.85	3	3.95	1.57	.195
SOL x REA x TCHR	7.87	3	2.62	1.04	.375
STR x SOL x REA x TCHR	.52	3	.17	.07	n.s.
Residual	886.80	352	2.52		
Total	1223.05	384	3.19		

TABLE 59

Adjusted Means and Standard Deviations of Student Scores on Text-and-Teacher-as-Source: Lower-Order Questions Subscale of Multiple-Choice Posttest Showing Reacting x Teacher Interaction

		Teacher 1	Teacher 2	Teacher 3	Teacher 4
Reacting	High	$\bar{X}$ = 5.83 SD = 1.51 N = 48	$\bar{X}$ = 5.41 SD = 1.40 N = 49	$\bar{X}$ = 4.79 SD = 1.86 N = 42	$\bar{X}$ = 5.47 SD = 1.52 N = 48
	Low	$\bar{X}$ = 5.15 SD = 1.73 N = 55	$\bar{X}$ = 5.55 SD = 1.50 N = 44	$\bar{X}$ = 5.47 SD = 1.60 N = 55	$\bar{X}$ = 5.18 SD = 1.61 N = 45

No significant treatment or teacher main effects appeared on the teacher-and-text-as-source: higher-order questions subscale, but there was a significant structuring x soliciting x reacting x teacher interaction (see Table 60). This four-way interaction, like most such higher-order interactions, is well-nigh uninterpretable. It indicates that in some degree the effects of each of the four variables depended on the level of each of the other three variables taken one or two or three at a time. It also means that in the list of 32 adjusted means on the teacher-and-text-as-source: higher-order questions subscale (four teachers x eight treatments), there would still be a significant amount of variance if the means for the four teachers and the eight treatments were made equal. Thus, the main effects of the teachers and the treatments are by themselves inadequate to explain all of the significant variance among the 32 means. As is shown in Table 61, the highest of the 32 means was that obtained by Teacher 1 using the low structuring-high soliciting-high reacting treatment. The lowest mean among the 32 was that obtained by Teacher 4 using the high structuring-high soliciting-high reacting treatment. The first of these means is 6.92, and the second is 4.61. Thus, there is a range of 2.31 points on this nine-item subscale between the effect of the most effective teacher-treatment combination and that of the least effective one, after variance between classes in scholastic aptitude (as measured by the vocabulary test) has been controlled through analysis of covariance.

In sum, significant teacher effects on the multiple-choice posttest of achievement appeared more frequently on the teacher-only subscales than on the teacher-and-text-as-source subscales. It makes sense that the test items on information taught only by the teacher would be more influenced by the teacher herself than would the items on material that the student could also have obtained from the text.

TABLE 60

Analysis of Covariance on Multiple-Choice Achievement Posttest: Higher-Order Questions with Text-and-Teacher-as-Source and Student as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Vocabulary	441.31	1	441.31	154.44	.001
Structuring: (STR)	.12	1	.12	.10	n.s.
Soliciting: (SOL)	.79	1	.79	.39	n.s.
Reacting: (REA)	1.96	1	1.96	1.10	.374
Teacher: (TCHR)	7.15	3	2.38	.63	n.s.
STR x SOL	1.36	1	1.35	.24	n.s.
STR x REA	.01	1	.01	.00	n.s.
STR x TCHR	3.63	3	1.21	.42	n.s.
SOL x REA	.32	1	.32	.46	n.s.
SOL x TCHR	6.02	3	2.01	.70	n.s.
REA x TCHR	5.30	3	1.77	.82	n.s.
STR x SOL x REA	2.72	1	2.72	.20	n.s.
STR x SOL x TCHR	12.49	3	4.16	1.45	.225
STR x REA x TCHR	9.23	3	3.08	1.08	.359
SOL x REA x TCHR	2.10	3	.70	.25	n.s.
STR x SOL x REA x TCHR	41.12	3	13.71	4.79	.003
Residual	1005.84	352	2.86		
Total	1541.63	384	4.02		

TABLE 61

Adjusted Means and Standard Deviations of Student Scores on Text-and-Teacher-as-Source: Higher-Order Questions Subscale of Multiple-Choice Posttest Showing Structuring x Soliciting x Reacting x Teacher Interaction

TRMT	TCHR	$\bar{X}$	SD	N	TRMT	TCHR	$\bar{X}$	SD	N
LLL	1	5.35	2.04	14	HLL	1	5.41	2.29	13
	2	4.89	1.66	8		2	5.59	1.97	11
	3	5.50	1.28	12		3	5.52	1.67	16
	4	5.68	1.54	12		4	5.17	1.79	10
LLH	1	4.83	1.84	11	HLH	1	6.22	1.21	13
	2	6.54	1.21	11		2	4.80	1.45	10
	3	5.28	1.75	9		3	5.36	1.25	11
	4	4.69	1.93	11		4	6.10	1.23	12
LHL	1	5.25	2.01	14	HHL	1	5.64	1.94	14
	2	5.29	1.56	13		2	5.08	1.10	12
	3	5.46	1.32	12		3	5.25	2.05	15
	4	4.89	1.96	10		4	5.34	1.75	13
LHH	1	6.92	0.99	11	HHH	1	5.46	1.75	13
	2	5.35	1.37	13		2	5.39	2.11	15
	3	4.66	2.19	10		3	5.92	1.06	12
	4	5.47	1.55	12		4	4.61	1.66	13

Essay and Attitude-Toward-Ecology Posttests

The analysis of covariance of the essay achievement posttest is presented in Table 62. As will be recalled, there were no significant treatment effects for essay achievement when the class was used as the unit of analysis (see Table 40). When the student was used as the unit of analysis, again no treatment effects occurred. But a significant main effect for teacher and several significant teacher x treatment interaction effects appeared. The means for these teacher effects are shown in Table 63. The highest adjusted essay achievement mean was attained by students of Teachers 1 and 4, and the lowest by students of Teacher 3. The means for the structuring x teacher interaction did not follow the same pattern as did the means for the structuring x teacher interaction on the teacher-only-as-source: higher-order questions subscale of the multiple-choice posttest (see Table 57). High structuring increased essay achievement if the structuring was done by Teacher 1. High structuring by the other teachers did not increase essay achievement. The means for the reacting x teacher interaction had the same rank order in several cases as the means for the same interaction on two subscales of the multiple-choice posttest (see Tables 57 and 59). Thus, high reacting by Teacher 1 clearly improved essay achievement (and also teacher-only higher-order and text-and-teacher lower order achievement), while low reacting by Teacher 2 consistently yielded the highest adjusted means on the essay achievement test (and also the two aforementioned multiple-choice test subscales).

TABLE 62

Analysis of Covariance on Log Transformation of Essay Achievement Posttest with the Student as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Vocabulary	3.40	1	3.40	62.56	.001
Structuring: (STR)	.11	1	.11	.72	n.s.
Soliciting: (SOL)	.04	1	.04	1.34	.331
Reacting: (REA)	.10	1	.10	.62	n.s.
Teacher: (TCHR)	.51	3	.17	3.11	.026
STR x SOL	.01	1	.01	.05	n.s.
STR x REA	.26	1	.26	2.28	.228
STR x TCHR	.48	3	.16	2.92	.033
SOL x REA	.01	1	.01	.06	n.s.
SOL x TCHR	.09	3	.03	.53	n.s.
REA x TCHR	.47	3	.16	2.89	.035
STR x SOL x REA	.00	1	.01	.03	n.s.
STR x SOL x TCHR	.57	3	.19	3.50	.016
STR x REA x TCHR	.35	3	.12	2.12	.096
SOL x REA x TCHR	.37	3	.13	2.29	.076
STR x SOL x REA x TCHR	.65	3	.22	3.98	.009
Residual	19.15	352	.05		
Total	26.67	384	.07		

TABLE 63

Adjusted Means and Standard Deviations of the Log Transformation of Student Scores on the Essay Achievement Posttest Showing Main Effects of Teacher, Structuring x Teacher Interaction, and Reacting x Teacher Interaction

	N	$\bar{X}$	SD
Teacher 1	103	0.39	0.24
Teacher 2	93	0.37	0.26
Teacher 3	96	0.30	0.22
Teacher 4	93	0.39	0.25

		Teacher 1	Teacher 2	Teacher 3	Teacher 4
Structuring	High	$\bar{X}$ = 0.43 SD = 0.24 N = 53	$\bar{X}$ = 0.30 SD = 0.25 N = 48	$\bar{X}$ = 0.28 SD = 0.20 N = 54	$\bar{X}$ = 0.38 SD = 0.27 N = 48
	Low	$\bar{X}$ = 0.36 SD = 0.25 N = 50	$\bar{X}$ = 0.44 SD = 0.27 N = 45	$\bar{X}$ = 0.33 SD = 0.24 N = 42	$\bar{X}$ = 0.40 SD = 0.25 N = 93
Reacting	High	$\bar{X}$ = 0.46 SD = 0.22 N = 48	$\bar{X}$ = 0.33 SD = 0.25 N = 49	$\bar{X}$ = 0.31 SD = 0.22 N = 42	$\bar{X}$ = 0.40 SD = 0.28 N = 48
	Low	$\bar{X}$ = 0.33 SD = 0.25 N = 55	$\bar{X}$ = 0.40 SD = 0.28 N = 44	$\bar{X}$ = 0.29 SD = 0.22 N = 54	$\bar{X}$ = 0.37 SD = 0.21 N = 45

Two significant higher-order interactions also appeared: structuring x soliciting x teacher and structuring x soliciting x reacting x teacher. As already noted, these higher-order interactions are difficult to interpret.

There was no significant main effect for teachers on student attitude. But Table 64 does show a significant structuring x teacher interaction on the attitude-toward-ecology posttest. The means in Table 65 reveal that high structuring by Teacher 3 had a negative effect on student attitude, but low structuring by Teacher 1 also had a negative effect on student attitude.

TABLE 64

Analysis of Covariance on Attitude-toward-Ecology Posttest
with the Student as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Vocabulary	10883.13	1	10883.13	296.35	.001
Structuring: (STR)	7.20	1	7.20	.04	n.s.
Soliciting: (SOL)	.00	1	.00	.00	n.s.
Reacting: (REA)	24.62	1	24.62	.35	n.s.
Teacher: (TCHR)	89.19	3	29.73	.81	n.s.
STR x SOL	101.11	1	101.11	1.59	.297
STR x REA	77.17	1	77.17	6.78	.079
STR x TCHR	548.88	3	182.96	4.98	.003
SOL x REA	1.86	1	1.86	.02	n.s.
SOL x TCHR	142.23	3	47.41	1.29	.276
REA x TCHR	208.92	3	67.84	1.90	.128
STR x SOL x REA	.16	1	.16	.00	n.s.
STR x SOL x TCHR	190.52	3	63.51	1.73	.159
STR x REA x TCHR	34.13	3	11.38	.31	n.s.
SOL x REA x TCHR	238.88	3	79.63	2.17	.090
STR x SOL x REA x TCHR	243.39	3	81.13	2.21	.085
Residual	12853.19	350	36.72		
Total	25636.16	382	67.11		

TABLE 65

Adju[illegible]eans and Standard Deviations of Student Scores on Attitude-
Toward-Ecology Posttest Showing Structuring x Teacher Interaction

		Teacher 1	Teacher 2	Teacher 3	Teacher 4
Structuring	High	$\bar{X}$ = 43.50 SD = 5.05 N = 53	$\bar{X}$ = 43.45 SD = 5.43 N = 47	$\bar{X}$ = 40.68 SD = 7.75 N = 54	$\bar{X}$ = 43.09 SD = 5.97 N = 48
	Low	$\bar{X}$ = 40.93 SD = 6.44 N = 50	$\bar{X}$ = 42.75 SD = 5.10 N = 45	$\bar{X}$ = 44.49 SD = 6.85 N = 43	$\bar{X}$ = 43.90 SD = 5.81 N = 45

Multiple-Choice Retention Test

Teacher effects virtually disappeared on the various subscales of the multiple-choice retention test. No teacher effects appeared on the teacher-only-as-source: lower-order questions subscale (see Table 66).

TABLE 66

Analysis of Covariance on Multiple-Choice Retention Test: Lower-Order Questions with Teacher-Only-as-Source and Student as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Vocabulary	236.15	1	236.15	91.90	.001
Structuring: (STR)	27.35	1	27.35	12.62	.036
Soliciting: (SOL)	7.48	1	7.48	1.44	.317
Reacting: (REA)	7.25	1	7.25	3.20	.171
Teacher: (TCHR)	11.34	3	3.78	1.47	.221
STR x SOL	5.12	1	5.10	1.60	.296
STR x REA	2.17	1	2.17	2.03	.249
STR x TCHR	6.50	3	2.17	.84	n.s.
SOL x REA	2.65	1	2.65	1.12	.369
SOL x TCHR	15.59	3	5.20	2.02	.109
REA x TCHR	6.79	3	2.26	.88	n.s.
STR x SOL x REA	.13	1	.13	.04	n.s.
STR x SOL x TCHR	9.57	3	3.19	1.24	.294
STR x REA x TCHR	3.22	3	1.07	.42	n.s.
SOL x REA x TCHR	7.09	3	2.36	.92	n.s.
STR x SOL x REA x TCHR	10.11	3	3.37	1.31	.269
Residual	907.09	353	2.57		
Total	1265.12	385	3.29		

But a main effect for teacher and a reacting x teacher interaction occurred on the teacher-only: higher-order questions subscale of the multiple-choice retention test (see Table 67). The means for these

TABLE 67

Analysis of Covariance on Multiple-Choice Retention Test: Higher-Order Questions with Teacher-Only-as-Source and Student as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Vocabulary	534.53	1	534.53	183.41	.001
Structuring: (STR)	.86	1	.86	.29	n.s.
Soliciting: (SOL)	6.49	1	6.49	4.85	n.s.
Reacting: (REA)	10.40	1	10.40	1.17	.360
Teacher: (TCHR)	57.44	3	19.15	6.57	.001
STR x SOL	.01	1	.01	.00	n.s.
STR x REA	20.57	1	20.57	14.69	.030
STR x TCHR	8.79	3	2.93	1.01	.392
SOL x REA	3.92	1	3.92	1.78	.274
SOL x TCHR	4.02	3	1.34	.46	n.s.
REA x TCHR	26.67	3	8.89	3.05	.028
STR x SOL x REA	2.13	1	2.13	1.45	.315
STR x SOL x TCHR	5.52	3	1.84	.65	n.s.
STR x REA x TCHR	4.20	3	1.40	.48	n.s.
SOL x REA x TCHR	6.59	3	2.20	.75	n.s.
STR x SOL x REA x TCHR	4.40	3	1.47	.50	n.s.
Residual	1028.80	353	2.91		
Total	1728.20	385	4.49		

effects are presented in Table 68. Teacher 2 had the highest mean ($\bar{X}$ = 5.20), and Teacher 3 had the lowest mean ($\bar{X}$ = 4.17). The reacting x teacher interaction showed that high reacting by Teachers 1 and 2 improved retention, but low reacting by Teacher 4 increased retention.

TABLE 68

Adjusted Means and Standard Deviations of Student Scores on Teacher-Only-as-Source: Higher-Order Questions Subscale of Multiple-Choice Retention Test Showing Main Effect of Teacher and Reacting x Teacher Interaction

	N	$\bar{X}$	SD
Teacher 1	103	5.03	1.42
Teacher 2	93	5.20	1.62
Teacher 3	97	4.17	2.10
Teacher 4	93	4.78	1.70

		Teacher 1	Teacher 2	Teacher 3	Teacher 4
Reacting	High	$\bar{X}$ = 5.36 SD = 1.31 N = 48	$\bar{X}$ = 5.55 SD = 1.48 N = 49	$\bar{X}$ = 4.47 SD = 1.95 N = 42	$\bar{X}$ = 4.50 SD = 1.62 N = 48
	Low	$\bar{X}$ = 4.75 SD = 1.46 N = 55	$\bar{X}$ = 4.82 SD = 1.70 N = 44	$\bar{X}$ = 3.94 SD = 2.20 N = 55	$\bar{X}$ = 5.08 SD = 1.74 N = 45

On the two text-and-teacher subscales, the only significant effect involving teachers was the structuring x soliciting x reacting x teacher interaction (see Tables 69 and 70 for analysis of covariance results and Tables and in Appendix E for the means reflecting this interaction effect).

TABLE 69

Analysis of Covariance on Multiple-Choice Retention Test: Lower-Order Questions with Text-and-Teacher-as-Source and Student as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Vocabulary	330.65	1	330.65	126.47	.001
Structuring: (STR)	.09	1	.09	.02	n.s.
Soliciting: (SOL)	8.14	1	8.14	1.47	.312
Reacting: (REA)	1.90	1	1.90	1.55	.302
Teacher: (TCHR)	15.60	3	5.28	1.99	.114
STR x SOL	3.30	1	3.30	1.47	.313
STR x REA	8.79	1	8.79	9.97	.049
STR x TCHR	17.60	3	5.87	2.24	
SOL x REA	3.63	1	3.63	.94	n.s.
SOL x TCHR	16.60	3	5.53	2.12	.096
REA x TCHR	3.69	3	1.23	.47	n.s.
STR x SOL x REA	4.24	1	4.24	.60	n.s.
STR x SOL x TCHR	6.75	3	2.25	.88	n.s.
STR x REA x TCHR	2.05	3	.88	.89	n.s.
SOL x REA x TCHR	11.55	3	3.85	1.47	.220
STR x SOL x REA x TCHR	21.07	3	7.02	2.69	.045
Residual	922.86	353	2.61		
Total	1379.96	385	3.58		

TABLE 70

Analysis of Covariance on Multiple-Choice Retention Test: Higher-Order Questions with Text-and-Teacher-as-Source and Student as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Vocabulary	542.46	1	542.46	176.82	.001
Structuring: (STR)	7.37	1	7.37	8.30	.062
Soliciting: (SOL)	2.60	1	2.60	.51	n.s.
Reacting: (REA)	4.64	1	4.64	3.37	.163
Teacher: (TCHR)	18.56	3	6.19	2.02	.110
STR x SOL	.205	1	.21	.11	n.s.
STR x REA	1.80	1	1.80	.32	n.s.
STR x TCHR	2.66	3	.89	.29	n.s.
SOL x REA	.29	1	.29	.17	n.s.
SOL x TCHR	15.38	3	5.13	1.67	.171
REA x TCHR	4.13	3	1.38	.44	n.s.
STR x SOL x REA	6.97	1	6.97	.39	n.s.
STR x SOL x TCHR	5.79	3	1.93	.63	n.s.
STR x REA x TCHR	17.11	3	5.70	1.86	.135
SOL x REA x TCHR	5.20	3	1.73	.57	n.s.
STR x SOL x REA x TCHR	53.36	3	17.79	5.80	.001
Residual	1082.94	353	3.07		
Total	1770.67	385	4.60		

Essay and Attitude-Toward-Ecology Retention Tests

Finally, we come to the retention data on the essay test and the attitude-toward-ecology inventory. Table 71 shows significant three-way (structuring x reacting x teacher) and four-way (structuring x soliciting x reacting x teacher) interactions on essay test retention.

TABLE 71

Analysis of Covariance on Log Transformation of Essay Retention Test with the Student as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Vocabulary	2.60	1	2.60	9.70	.001
Structuring: (STR)	.041	1	.04	.26	n.s.
Soliciting: (SOL)	.30	1	.30	2.99	.182
Reacting: (REA)	.77	1	.77	16.76	.025
Teacher: (TCHR)	.14	3	.05	.88	.n.s.
STR x SOL	.14	1	.14	1.22	.351
STR x REA	.01	1	.01	.02	n.s.
STR x TCHR	.48	3	.18	3.09	.028
SOL x REA	.03	1	.03	.43	n.s.
SOL x TCHR	.30	3	.10	1.90	.128
REA x TCHR	.14	3	.05	.88	n.s.
STR x SOL x REA	.03	1	.03	.06	n.s.
STR x SOL x TCHR	.34	3	.11	2.16	.091
STR x REA x TCHR	.83	3	.28	5.28	.002
SOL x REA x TCHR	.24	3	.08	1.51	.210
STR x SOL x REA x TCHR	1.30	3	.43	8.28	.001
Residual	18.48	353	.05		
Total	26.23	385	.09		

A structuring x teacher interaction had occurred on the attitude-toward-ecology posttest and recurred on the attitude-toward-ecology retention test (see Table 72). The adjusted means for the structuring x

TABLE 72

Analysis of Covariance on Attitude-toward-Ecology Retention Test with the Student as the Unit of Analysis

Source	SS	df	MS	F	p
Covariate: Attitude-toward-Ecology Pretest	11510.39		11510.39	255.05	.001
Structuring: (STR)	7.32	1	7.32	.04	n.s.
Soliciting: (SOL)	2.76	1	2.76	[illegible]	n.s.
Reacting: (REA)	.25	1	.25	.01	n.s.
Teacher: (TCHR)	102.58	3	34.19	.87	n.s.
STR x SOL	14.68	1	14.68	.57	n.s.
STR x REA	28.56	1	28.56	1.58	.298
STR x TCHR	593.80	3	197.94	3.87	.010
SOL x REA	2.68	1	2.68	.05	n.s.
SOL x TCHR	65.81	3	21.94	.43	n.s.
REA x TCHR	127.51	3	42.50	.83	n.s.
STR x SOL x REA	50.30	1	50.30	.59	n.s.
STR x SOL x TCHR	77.23	3	25.75	.50	n.s.
STR x REA x TCHR	54.22	3	18.07	.35	n.s.
SOL x REA x TCHR	176.68	3	58.89	1.15	.328
STR x SOL x REA x TCHR	257.76	3	85.92	1.68	.169
Residual	17901.04	350	51.15		
Total	30995.09	382	81.14		

teacher interaction on attitude retention differed in the same directions as those on the attitude posttest (see Tables 65 and 73). On both the posttest and retention tests students of Teachers 1 and 2 had a more favorable attitude toward the subject matter when they were taught with high structuring. Students of Teachers 3 and 4 had a better attitude when taught with low structuring (see Table 73).

TABLE 73

Adjusted Means and Standard Deviations of Student Scores on Attitude-toward-Ecology Retention Test Showing Structuring x Teacher Interaction

		Teacher 1	Teacher 2	Teacher 3	Teacher 4
Structuring	High	$\bar{X}$ = 42.20 SD = 6.06 N = 53	$\bar{X}$ = 41.01 SD = 6.73 N = 47	$\bar{X}$ = 38.49 SD = 8.49 N = 54	$\bar{X}$ = 40.25 SD = 7.01 N = 48
	Low	$\bar{X}$ = 39.32 SD = 7.95 N = 50	$\bar{X}$ = 39.59 SD = 5.15 N = 44	$\bar{X}$ = 41.76 SD = 7.65 N = 43	$\bar{X}$ = 42.32 SD = 6.81 N = 45

A Read-Only Treatment Compared with the Recitation Strategy

How much would students learn from merely reading the curriculum material without the help of the teacher?* A follow-up experiment was carried out during the spring of 1976 to answer this question. This investigation was intended to determine the extent to which merely reading the materials, without the intervention or assistance of a teacher, could contribute to student achievement of the objectives of the ecology unit. While the results in the preceding sections show that students learned a substantial amount of ecology from the combination of reading the curriculum materials and interacting with the teacher, the main experiment did not assess the independent contribution of each of the two components. The follow-up experiment attempted to make such an assessment by presenting sixth graders with only the ecology curriculum materials.

Method

Sixth graders from three classrooms served as subjects for the experiment. To facilitate comparisons, the classrooms chosen belonged to teachers who had cooperated in the original study. The classrooms were in three different school districts in the Palo Alto (California) area.

*We are grateful to Walter Mischel for raising this question.

Students in each classroom were randomly assigned to one of two treatment conditions. In the first condition, students received curriculum materials identical to those used in the previous study. In the second condition, students received the original curriculum materials with supplementary pages. These supplements included information for which only the teachers had served as the source in the original study. The nine ecology lessons were presented over nine consecutive days of schooling. Students received all the time necessary to read the materials: this time never exceeded fifteen minutes. A research staff member was present in each classroom each day to hand out and collect the materials, as well as to make casual observations.

The students were given the same pretests, posttests, and retention tests that had been used in the original study. The pretests measured vocabulary, attitude toward ecology, and true-false knowledge of ecology; they were administered the week before the treatment began. The posttests, administered on the day following the ninth lesson, consisted of the attitude-toward-ecology measure, the essay test on ecology, and the multiple-choice achievement test. As will be recalled, the items on the multiple-choice test were constructed so that half dealt with ideas for which the teacher and text served as source, and half dealt with ideas for which only the supplementary materials (the teacher only, in the original experiment) served as source. The retention tests, identical to the posttests, except for the addition of the true-false-? test of knowledge of ecology, were given to the students two weeks after the posttest.

Results

The pretest measures for the three classes used in this experiment were compared with the pretest measures obtained during the study of the previous year for classes belonging to the same teachers. Table 74 presents this information. The mean vocabulary score of the read-only Class 3 students (24.00) showed the greatest departure from the mean of the corresponding curriculum + teaching condition scores of the students of the same teacher during the previous year (19.96). This difference in ability in this class can be explained by the fact that students of

TABLE 74

Pretest Scores of Students in the Read-Only and Curriculum + Teacher Treatments

		Treatment Groups					
		Read Only			Curriculum + Teacher		
	Teacher	N	Mean	SD	N	Mean	SD
Vocabulary Test							
	1	20	23.00	4.78	25	23.32	6.08
	2	24	20.04	4.06	25	18.48	4.23
	3	21	24.00	4.55	23	19.96	6.04
Attitude-toward-Ecology Inventory	1	20	41.45	6.78	25	45.92	5.92
	2	24	41.04	5.28	25	44.56	6.75
	3	21	46.43	8.26	23	45.91	7.81
True-False-? Test of Knowledge of Ecology	1	20	7.00	3.03	25	6.88	2.22
	2	24	7.50	2.80	25	8.20	2.87
	3	21	9.05	2.42	23	7.17	2.06

Teacher 3 for this experiment were considered "mentally gifted," whereas students in this class during the previous y were not thus classified. The students of Teachers 1 and 2 appear to have similar mean performances on the vocabulary and true-false-? measures across the two treatments in the two successive years. The students of both these teachers from the curriculum + teaching condition had higher mean scores on the attitude-toward-ecology inventory than the students of the same teachers in the read only condition.

Table 75 presents the adjusted posttest means for the students of the three teachers in the read-only and curriculum + teaching conditions. To obtain the most direct comparison, we contrasted the read-only classes with the curriculum + teaching classes of the same teacher from the previous year. In addition, both the read-only and curriculum + teaching conditions were split into two smaller treatment groups. The read-only students were divided into those who received the original form of the reading material and those who received the original+supplementary material. The students in the curriculum+teaching condition were divided into two half-classes which received different teaching recitation variations (see footnote in Table 75).

For each teacher's class, on each posttest measure, an analysis of covariance was performed across the four treatment groups. The resulting F and p values are reported. The F-ratio for the multiple-choice achievement posttest total scores was significant at the .01 level for all three classes. Students in classes who received teaching in addition to the curriculum had an overall performance superior to students who received only the curriculum. The multiple-choice subscales consisting of the lower-order teacher-only and higher-order teacher-only-as-source items appear to account for much of this difference. Consistent with the total score, these subscales show the superior performance of the students in the curriculum + teaching condition. It might have been expected that the lower scores of the read-only students on the teacher-only items could be explained, in part, by the fact that the original version of the curriculum, given to half of the read-only students, did not contain the teacher-only item content. Strangely enough, the read-only students who received only the original curriculum material did no worse than the read-only students who received the supplementary reading material, except for the lower-order, teacher-only-as-source subscale. Nevertheless, the curriculum + teaching condition maintained a higher performance than the read-only original + supplement treatment group, which did receive the teacher-only-as-source content.

Classes 1 and 3 show significant F-ratios for the essay achievement posttest means. As was true of the multiple-choice achievement posttest results, students who received teaching as well as reading matter performed better. Differences across treatments in attitude-toward-ecology posttest scores were not significant.

The adjusted retention test means presented in Table 76 generally are lower than the corresponding posttest means in Table 75. The adjusted multiple-choice achievement retention test total means indicate that only the curriculum + teaching condition scores for Class 1 are significantly

TABLE 75

Adjusted Posttest Means of the Read-Only and Curriculum + Teaching Groups

Variable	Teacher		Treatment: Without Teacher: Read Only (Original)	Treatment: Without Teacher: Read Only (Original+ Supplement)	Treatment: With Teacher: 1/2-Class A[1]	Treatment: With Teacher: 1/2-Class B[2]	F	p
Multiple-Choice		M	13.75	12.81	19.02	19.57		
Achievement	1	SD	4.60	5.29	5.94	4.29	4.99	0.005
Posttest Total		N	11	9	10	13		
		M	15.47	14.16	20.53	20.64		
	2	SD	2.38	4.53	4.82	6.81	5.50	0.003
		N	11	13	12	13		
		M	15.39	17.28	20.70	22.93		
	3	SD	4.42	7.34	3.70	3.92	4.84	0.006
		N	12	9	12	11		
Multiple-Choice		M	4.05	2.78	4.57	4.73		
Achievement Posttest,	1	SD	1.69	1.60	1.55	1.31	3.22	0.033
Lower-Order, Text-and-		N	11	9	10	13		
Teacher-as-Source Items		M	4.16	4.21	5.56	5.09		
	2	SD	1.91	1.80	1.78	1.82	1.62	0.198
		N	11	13	12	13		
		M	4.07	3.74	5.64	6.35		
	3	SD	1.37	2.20	1.32	1.57	5.71	0.003
		N	12	9	12	11		
Multiple-Choice		M	4.34	3.68	4.92	5.37		
Achievement Posttest,	1	SD	1.48	2.57	1.96	1.75	1.43	0.248
Higher-Order, Text-and-		N	11	9	10	13		
Teacher-as-Source Items		M	4.93	4.07	5.52	5.43		
	2	SD	0.97	1.97	1.27	2.29	2.09	0.114
		N	11	13	12	13		
		M	4.70	5.12	5.71	5.61		
	3	SD	1.98	1.93	1.54	1.96	0.74	n.s.
		N	12	9	12	11		
Multiple-Choice		M	2.55	3.78	4.49	4.04		
Achievement Posttest,	1	SD	1.11	1.81	1.35	1.54	3.53	0.024
Lower-Order, Teacher-		N	11	9	10	13		
Only-as-Source Items		M	2.93	2.97	4.61	4.95		
	2	SD	0.96	1.01	1.31	1.87	7.29	0.001
		N	11	13	12	13		
		M	3.00	4.21	5.06	5.38		
	3	SD	1.57	1.81	1.16	1.27	5.53	0.003
		N	12	9	12	11		

TABLE 75 (continued)

Variable	Teacher		Without Teacher: Read Only (Original)	Without Teacher: Read Only (Original+ Supplement)	With Teacher: 1/2-Class A[1]	With Teacher: 1/2-Class B[2]	F	p
Multiple-Choice Achievement Posttest, Higher-Order, Teacher-Only-as-Source Items		M	2.82	2.56	5.03	5.44		
	1	SD	1.63	1.87	2.14	1.72	6.64	0.001
		N	11	9	10	13		
		M	3.45	2.92	4.83	5.17		
	2	SD	1.08	1.63	1.57	2.09	4.89	0.005
		N	11	13	12	13		
		M	3.62	4.17	4.30	5.58		
	3	SD	1.96	2.59	1.50	0.95	2.34	0.087
		N	12	9	12	11		
Log Transformation of Essay Posttest on Ecology		M	0.05	0.14	0.25	0.42		
	1	SD	0.23	0.28	0.21	0.19	5.32	0.004
		N	11	9	10	13		
		M	0.25	0.22	0.19	0.24		
	2	SD	0.21	0.23	0.20	0.20	0.18	n.s.
		N	11	13	12	13		
		M	0.16	0.22	0.40	0.48		
	3	SD	0.27	0.25	0.18	0.19	6.25	0.002
		N	12	9	12	11		
Attitude-toward-Ecology Posttest		M	43.13	38.32	39.89	42.05		
	1	SD	4.83	8.16	6.94	7.20	1.02	0.397
		N	11	9	10	13		
		M	45.86	45.69	41.71	43.60		
	2	SD	4.57	4.63	5.15	5.02	1.73	0.174
		N	11	13	12	13		
		M	45.01	47.04	45.92	44.85		
	3	SD	3.66	4.[illegible]	5.30	7.41	0.38	n.s.
		N	12	9	12	11		

[1] Teacher 1's students received Treatment LHL.
Teacher 2's students received Treatment [illegible]LL.
Teacher 3's students received Treatment LLL.

[2] Teacher 1's students received Treatment HHL.
Teacher 2's students received Treatment HLL.
Teacher 3's students received Treatment HLL.

TABLE 76

Adjusted Retention Test Means of the Read-Only and Curriculum + Teaching Groups

			Treatment					
			Without Teacher		With Teacher			
Variable	Teacher		Read Only (Original)	Read Only (Original+ Supplement)	1/2-Class 1 A[1]	1/2-Class 2 B[2]	F	p
Multiple-Choice Achievement Retention Test Total	1	M	14.85	13.37	15.43	19.99		
		SD	5.58	5.75	6.60	4.39	2.94	0.045
		N	11	9	10	13		
	2	M	14.33	14.50	16.49	18.34		
		SD	3.63	4.75	5.98	6.22	1.27	0.297
		N	11	13	12	13		
	3	M	15.66	17.27	19.52	21.49		
		SD	4.67	6.66	3.71	4.41	2.28	0.093
		N	12	9	12	11		
Multiple-Choice Achievement Retention Test, Lower-Order, Text-and-Teacher-as-Source Items	1	M	4.23	2.67	3.95	4.82		
		SD	1.94	1.78	2.73	1.55	2.00	0.129
		N	11	9	10	13		
	2	M	3.96	3.22	4.55	4.42		
		SD	2.06	1.86	1.74	1.67	1.23	0.309
		N	11	13	12	13		
	3	M	3.80	4.03	4.97	5.62		
		SD	1.90	2.28	0.98	1.38	2.04	0.122
		N	12	9	12	11		
Multiple-Choice Achievement Retention Test, Higher-Order, Text-and-Teacher-as-Source Items	1	M	4.81	4.23	4.10	4.91		
		SD	1.83	2.08	1.85	1.80	0.49	n.s.
		N	11	9	10	13		
	2	M	3.99	4.54	4.66	5.37		
		SD	1.96	1.62	1.55	1.99	1.12	0.353
		N	11	13	12	13		
	3	M	4.60	4.54	5.04	5.51		
		SD	2.17	1.71	1.34	2.07	0.20	n.s.
		N	12	9	12	11		
Multiple-Choice Achievement Retention Test, Lower-Order, Teacher-Only-as-Source Items	1	M	2.51	3.23	2.68	4.58		
		SD	1.14	1.61	1.38	1.31	5.72	0.003
		N	11	9	10	13		
	2	M	2.33	3.21	3.39	3.70		
		SD	0.99	1.62	1.62	1.82	1.57	0.209
		N	11	13	12	13		
	3	M	3.16	4.08	4.81	5.07		
		SD	1.73	1.49	1.47	1.30	3.17	0.034
		N	12	9	12	11		

TABLE 76 (continued)

Variable	Teacher		Treatment: Without Teacher: Read Only (Original)	Treatment: Without Teacher: Read Only (Original+ Supplement)	Treatment: With Teacher: 1/2-Class A[1]	Treatment: With Teacher: 1/2-Class B[2]	F	p
Multiple-Choice Achievement Retention Test, Higher-Order, Teacher-Only-as-Source Items		M	3.30	3.23	4.71	5.68		
	1	SD	1.89	2.09	2.21	1.63	3.78	0.018
		N	11	9	10	13		
		M	4.05	3.54	3.88	4.86		
	2	SD	1.49	1.86	2.67	1.78	0.54	n.s.
		N	11	13	12	13		
		M	4.11	4.62	4.71	5.29		
	3	SD	2.25	2.44	1.51	1.76	0.63	n.s.
		N	12	9	12	11		
Log Transformation of Essay Retention Test on Ecology		M	0.07	0.15	0.10	0.17		
	1	SD	0.19	0.25	0.19	0.19	0.51	n.s.
		N	11	9	10	13		
		M	0.09	0.20	0.08	0.19		
	2	SD	0.12	0.25	0.15	0.22	1.52	0.223
		N	11	13	12	13		
		M	0.16	0.12	0.33	0.41		
	3	SD	0.20	0.26	0.26	0.27	4.08	0.013
		N	12	9	12	11		
Attitude-toward-Ecology Retention Test		M	42.04	34.61	39.20	40.74		
	1	SD	5.02	5.65	6.13	7.62	2.51	0.072
		N	11	9	10	13		
		M	42.99	43.29	40.25	41.85		
	2	SD	5.52	6.11	4.31	6.06	0.88	n.s.
		N	11	13	12	13		
		M	43.64	44.25	45.83	41.38		
	3	SD	3.75	2.56	6.80	9.20	1.09	0.366
		N	12	9	12	11		
True-False-? Knowledge-of-Ecology Retention Test		M	10.77	10.15	10.55	12.52		
	1	SD	2.27	1.15	2.73	3.67	1.03	0.393
		N	11	9	9	13		
		M	8.77	10.42	11.72	11.10		
	2	SD	1.85	3.00	2.83	3.85	2.11	0.111
		N	11	13	12	13		
		M	11.39	11.23	11.12	11.13		
	3	SD	1.27	1.62	3.20	3.44	0.08	n.s.
		N	12	9	12	11		

[1] Teacher 1's students received Treatment LHL.
Teacher 2's students received Treatment LLL.
Teacher 3's students received Treatment LLL.

[2] Teacher 1's students received Treatment HHL.
Teacher 2's students received Treatment HLL.
Teacher 3's students received Treatment HLL.

191 192

greater than the read-only condition scores. This suggests that while the beneficial learning attributable to teaching is evident at the time of the day-after posttest, the margin of this benefit may decrease over time. As was true of the posttest data, the multiple-choice retention test subscales for teacher-only items yielded significant F-ratios in some classes. The three other retention test measures--attitude-toward-ecology, essay, and true-false-?--did not show substantial differences across treatments, with the exception of one class on the essay test.

Table 77 presents the adjusted posttest means for the eight recitation strategy treatment groups in the previous experiment and also the adjusted posttest means for the two read-only groups from this experiment. The mean in each cell is adjusted for prior ability of the group as measured by the vocabulary pretest. The analysis of covariance across all 10 treatments resulted in significant F-ratios for the multiple-choice posttest total and all of its subscales except the higher-order text-and-teacher-as-source items. An examination of the individual treatment scores reveals that these differences resulted largely from the lower scores in the read-only treatments. Furthermore, a comparison of the means from the least effective recitation teaching strategy, namely the low-high-low treatment, with the highest read-only means, shows that the curriculum + teaching condition is superior to the read-only condition for every multiple-choice posttest category. This contrast holds for the essay achievement posttest results as well, with the high-high-low treatment being the least effective recitation strategy.

The same 10-treatment comparison for the retention tests is given in Table 78. These results appear to be quite similar to those in Table 77. Again, the curriculum + teaching treatments produced significantly higher multiple-choice achievement retention test scores than the read-only treatments. As was the case with the class comparisons in Tables 75 and 76, the lower F-ratios in Table 78 (as compared to Table 77) indicate that the benefits of teaching had decreased by the time of the retention test. Still, the gain attributable to teaching remains significant. The fact that this margin did not remain significant in Table 76 can be explained by the fact that the half-classes of Teachers 1, 2, and 3

TABLE 77

Adjusted Posttest Means of the Eight Curriculum + Teaching Treatment Groups and the Two Read-Only Groups

Variable		HHH (N=54)	HHL (N=53)	HLH (N=46)	HLL (N=50)	LHH (N=46)	LHL (N=49)	LLH (N=42)	LLL (N=46)	Read Only (Original) (N=34)	Read Only (Supplement) (N=31)	F	p
Multiple-Choice Achievement Posttest Total	M	19.83	20.22	21.84	21.35	20.21	19.18	21.66	20.25	14.88	14.67	11.22	0.001
	SD	4.44	4.33	3.97	5.08	4.65	4.94	4.46	4.46	3.91	5.76		
Multiple-Choice Achievement Posttest, Lower-Order, Text-and-Teacher-as-Source Items	M	5.06	5.35	5.62	5.75	5.06	5.06	6.02	5.28	4.09	3.66	7.33	0.001
	SD	1.55	1.37	1.51	1.68	1.67	1.74	1.52	1.64	1.61	1.91		
Multiple-Choice Achievement Posttest, Higher-Order, Text-and-Teacher-as-Source Items	M	5.35	5.38	5.71	5.46	5.63	5.27	5.37	5.42	4.66	4.26	2.36	0.013
	SD	1.72	1.75	1.37	1.88	1.71	1.69	1.80	1.64	1.52	2.16		
Multiple-Choice Achievement Posttest, Lower-Order, Teacher-Only-as-Source Items	M	4.75	4.67	5.29	4.83	4.37	4.33	4.83	4.72	2.83	3.58	8.36	0.001
	SD	1.57	1.44	1.67	1.77	1.37	1.36	1.33	1.48	1.23	1.57		
Multiple-Choice Achievement Posttest, Higher-Order, Teacher-Only-as-Source Items	M	4.67	4.83	5.23	5.31	5.15	4.52	5.45	4.83	3.31	3.18	7.74	0.001
	SD	1.66	1.65	1.37	1.53	1.82	1.84	1.87	1.89	1.60	2.06		
Log Transformation of Essay Posttest on Ecology	M	0.32	0.36	0.35	0.36	0.40	0.34	0.46	0.33	0.15	0.20	4.89	0.001
	SD	0.27	0.23	0.27	0.22	0.22	0.29	0.23	0.23	0.25	0.24		
Attitude-toward-Ecology Posttest	M	42.92	42.95	41.77	41.99	42.97	41.61	43.92	42.68	44.68	43.94	1.14	0.334
	SD	5.66	5.74	5.15	8.07	5.69	6.63	7.00	5.35	4.38	6.71		

TABLE 78

Adjusted Retention Test Means of the Eight Curriculum + Teaching Treatment Groups and the Two Read-Only Groups

Variable		HHH (N=54)	HHL (N=53)	HLH (N=46)	HLL (N=50)	LHH (N=46)	LHL (N=49)	LLH (N=42)	LLL (N=46)	Read Only (Original) (N=34)	Read Only (Supplement) (N=31)	F	P
Multiple Choice Achievement Posttest Total	M	18.07	19.93	20.72	19.17	19.19	17.09	20.15	17.96	14.96	14.97	6.25	0.001
	SD	5.77	4.94	3.83	5.72	4.38	5.61	3.91	5.13	4.59	5.67		
Multiple-Choice Achievement Posttest, Lower-Order, Text-and-Teacher-as-Source Items	M	4.26	4.97	5.25	4.89	5.01	4.54	5.10	4.61	3.99	3.30	4.71	0.001
	SD	1.53	1.59	1.54	1.75	1.50	2.12	1.43	1.49	1.91	1.97		
Multiple-Choice Achievement Posttest, Higher-Order, Text-and-Teacher-as-Source Items	M	5.06	5.41	5.65	5.23	5.32	4.75	5.21	5.01	4.47	4.45	1.91	0.048
	SD	1.98	1.89	1.35	1.81	1.80	1.93	1.63	1.72	1.97	1.73		
Multiple-Choice Achievement Posttest, Lower-Order, Teacher-Only-as-Source Items	M	4.30	4.48	4.64	4.25	3.79	3.51	4.47	3.85	2.68	3.47	5.77	0.001
	SD	1.83	1.66	1.64	1.84	1.30	1.49	1.27	1.64	1.35	1.58		
Multiple-Choice Achievement Posttest, Higher-Order, Teacher-Only-as-Source Items	M	4.46	5.08	5.18	4.80	5.07	4.29	5.38	4.49	3.38	3.76	3.91	0.001
	SD	1.93	1.55	1.42	1.86	1.82	1.81	1.42	1.95	1.89	2.11		
Log Transformation of Essay Posttest on Ecology	M	0.22	0.15	0.32	0.23	0.23	0.17	0.29	0.14	0.11	0.17	3.42	0.001
	SD	0.27	0.19	0.29	0.23	0.27	0.21	0.27	0.22	0.17	0.25		
Attitude-toward-Ecology Posttest	M	39.56	41.38	40.50	39.64	40.92	39.81	40.51	40.75	42.91	41.05	0.84	n.s.
	SD	6.53	5.42	7.42	9.35	7.41	7.47	7.26	6.26	4.69	6.55		
True-False-? Knowledge-of-Ecology Retention Test	M	11.27	11.79	12.27	11.37	11.63	11.54	11.07	10.57	10.34	10.58	2.01	0.037
	SD	3.23	2.98	1.84	3.02	2.78	2.96	2.59	3.06	2.10	2.20		

received some of the least successful curriculum + teaching treatments. The essay achievement retention test scores in Table 78 are consistent with the posttest results. The comparison across the true-false-? retention test means of the 10 treatments showed significant differences at the .05 level, with curriculum + teaching treatments producing higher scores than the read-only treatments in all but one instance.

Conclusions

In sum, the results of this read-only experiment, when compared with the results of curriculum + teaching in the previous study, support the conclusion that teaching contributes to student achievement beyond what occurs from merely reading the curriculum materials. This gain in achievement is most evident in the scores from the most content-specific measures, in this case, the multiple-choice achievement test and especially the lower-order teacher-only-as-source subscale. While the advantage of teaching declines over time, it still remains substantial for the more effective classroom recitation treatments. In addition, results from the read-only condition suggest that merely reading the curriculum can contribute to student learning. This inference is based on an almost three-item mean gain between the pretest and retention means on the true-false-? test of knowledge of ecology.

One limitation that must be considered in comparing this experiment with the previous study is that amount of time for treatment was confounded with the two types of conditions. Students were exposed to the curriculum materials for a maximum of 15 minutes per day in the read-only condition; this seemed to be all the time they could profitably use in this condition. Students in the curriculum + teaching condition received about 35-40 minutes of treatment per day. While this time difference alone might account for the overall lower performance by read-only students, it can be argued that teaching is the only method by which students can be motivated to keep attending to the information.

Supplementary Analyses

Aptitude-Treatment Interaction Effects

Research on teacher effectiveness seldom has considered the question of whether different teaching acts or strategies have differential influence on students as a function of variations in student aptitudes. In this context, aptitudes are construed broadly as any measure predictive of learning. Hence, an objective of these analyses was to explore for the presence of aptitude-treatment interactions (ATI).

The analyses used to examine the data for ATI took the form of stepwise regression analyses. The predictor variables were grouped into four distinct categories, namely, aptitude main effects, treatment main and interaction effects, teacher main effects, and ATI effects. The categories were assigned priorities for entering the regression model in the order listed above. The variables within a category were entered simultaneously, except for the ATI effects, which were allowed to enter in a free stepwise fashion according to an F-to-enter statistic. The procedure means that all the treatment, teacher, and ATI prediction terms were not permitted to enter the regression equation until each aptitude predictor had been tested for entry into the model. Correspondingly, teacher and ATI terms were not allowed to enter the regression equations until treatment variables were tested and entered or rejected as influential predictor variables, and so on.

The decision to assign priority levels in this order reflects the effort to obtain conceptual parsimony in accounting for variation in student achievement or student attitude. Specifically, if it were possible to explain all the variation in a dependent variable on the basis of student aptitudes, factors determined prior to educational intervention, then there is no reason to examine various methods for training teachers or methods of teaching in the hope of finding one better than another. Similarly, if variation in student achievement were best explained by student aptitudes and the way the teacher taught, then there would be no need to test the differential influence of unexplained teacher variation or ATI. Following this reasoning one step further, if student aptitudes, treatment, and teacher effects explained the variation in student achievement, then there is no need to complicate matters by considering ATI.

The criterion for judging the statistical significance of an aptitude-interaction term is that the term account for a significant ($p < .01$) portion of the variance. The F-test (Kerlinger & Pedhazur, 1973) estimates the probability that the amount of variance accounted for by a particular regression term could have occurred by chance. The .01 level was chosen so that only statistically significant ATI terms were identified.

The following aptitudes were used in these analyses: the vocabulary test; the attitude-toward-ecology pretest; the true-false-? pretest; student preference for structuring pretest; student preference for soliciting pretest; student preference for reacting pretest; the word list pretest; the groups of words pretest; the object-number pretest; the word pairs pretest; and student sex. Aptitudes were deviated about the grand mean to reduce multicollinearity among aptitudes and ATI predictors.

The following dependent variables were used in these analyses: multiple-choice lower-order questions, text-and-teacher posttest; multiple-choice higher-order questions, text-and-teacher posttest; multiple-choice lower-order questions, teacher-only posttest; multiple-choice higher-order questions, teacher-only posttest; attitude-toward-ecology posttest; and the log transformation of the essay posttest. The same dependent variables were used in their retention test roles, and additionally, the true-false-? was also used in the retention tests.

The results of these regression analyses are presented in Tables 79 and 80 for the posttest dependent variables and the retention test dependent variables, respectively. For each predictor the following are provided: the F-statistic testing the statistical significance of amount of variance accounted for by the predictor, the unstandardized regression coefficient, the amount of variance accounted for by the predictor, and the cumulative proportion of variation in the dependent variable absorbed by <u>all</u> predictors in the model.

TABLE 79

Generalized Regression Analyses for Posttest Measures

Dependent Variable	Predictor Variable	F[1]	b	Proportion of Variance
Multiple-choice Lower-Order Questions, Text-and-Teacher Posttest	Vocabulary	107.81	.11	.19
	Word Pairs	11.00	.06	.02
	Soliciting	9.57	-.24	.02
	Groups of words by STR x REA	9.15	.08	.02
		(341)[2]		(.39)[3]
Multiple-choice Higher-Order Questions, Text-and-Teacher Posttest	Vocabulary	166.84	.18	.28
	Preference for STR by Reacting	7.63	.09	.01
		(338)[2]		(.42)[3]
Multiple-choice Lower-Order Questions, Teacher-Only Posttest	Vocabulary	97.24	.09	.18
	Word Pairs	6.67	.07	.01
	Sex	8.47	.22	.02
	Teacher 3 vs. Teacher 4	8.18	-.33	.01
	Preference for SOL by STR x SOL	8.80	.15	.02
	Preference for REA by STR x REA	6.65	.07	.01
	Word Pairs by STR x SOL	6.87	.06	.01
		(333)[2]		(.40)[3]
Multiple-choice Higher-Order Questions, Teacher-Only Posttest	Vocabulary	154.28	.16	.26
	Attitude-Toward-Ecology	6.72	.03	.01
	Word Pairs	10.21	.07	.02
		(338)[2]		(.43)[3]
Log-Transformation of Essay Posttest	Vocabulary	66.41	.01	.13
	Groups of Words	7.84	.01	.02
	Teacher	10.31	-.08	.02
	Preference for SOL by STR x SOL x REA	9.94	.02	.02
		(337)[2]		(.35)[3]
Attitude-Toward-Ecology Posttest	Vocabulary	16.29	-.07	.02
	Attitude-Toward-Ecology Pretest	304.58	.67	.40
	Preference for STR by STR	8.95	.50	.01
	Vocabulary by STR x REA	6.98	.15	.01
	Groups of Words by SOL x REA	7.11	-.30	.01
		(329)[2]		(.57)[3]

[1]The critical value is $_{.01}F_{(1,\infty)} = 6.63$

[2]Degrees of freedom for residual

[3]Total amount of variance explained by full model, including terms not achieving statistical significance according to the .01 criterion.

159

TABLE 80

Generalized Regression Analyses for Retention Measures

Dependent Variable	Predictor Variable	F[1]	b	Proportion of Variance
Multiple-choice Lower-Order Questions, Text-and-Teacher Retention Test	Vocabulary	147.68	.15	.24
	Attitude-Twoard-Ecology	12.22	.04	.02
	Object-Number	12.65	.12	.02
	Word Pairs	8.11	.07	.01
	Preference for REA by STR x REA	8.88	.07	.01
		(335)[2]		(.45)[3]
Multiple-choice Higher-Order, Text-and-Teacher Retention Test	Vocabulary	191.27	.19	.30
	Preference for SOL by SOL	9.29	.12	.01
	Object-Number by STR x SOL x REA	7.03	.10	.01
	True-False-? by STR	7.17	.09	.01
		(336)[2]		(.47)[3]
Multiple-choice Lower-Order Questions, Teacher Only Retention Test	Vocabulary	104.09	.12	.19
	Attitude-Toward-Ecology	8.97	.03	.02
	Word Pairs	9.73	.07	.02
	Structuring	11.23	.32	.02
	Preference for REA by STR x REA	8.35	.06	.01
		(339)[2]		(.39)[3]
Multiple-choice Higher-Order Questions, Teacher Only Retention Test	Vocabulary	231.78	.19	.31
	Attitude-Toward-Ecology	14.72	.04	.02
	Word Pairs	19.76	.09	.03
	Teacher 3 vs. Teacher 4	21.70	-.65	.03
	Sex by STR	11.99	.31	.02
	Attitude-Toward-Ecology by STR	7.07	.03	.01
	Word Lists by STR x REA	7.01	.01	.01
		(329)[2]		(.56)[3]
Log-Transformation of Essay Retention Test	Vocabulary	52.56	.01	.10
	Attitude-Toward-Ecology	6.96	.00	.01
	Object-Number	13.37	.02	.03
	Sex	9.04	-.03	.02
	Reacting	13.64	.05	.03
		(332)[2]		(.37)[3]

(cont'd.)

TABLE 80 (continued)

Dependent Variable	Predictor Variable	F[1]	b	Proportion of Variance
Attitude-Toward-Ecology Retention Test	Vocabulary	15.93	.04	.02
	Attitude-Toward-Ecology	264.98	.68	.35
	Sex	12.23	-1.52	.02
	Attitude by STR x REA	12.38	.09	.02
	Groups of Words by SOL x REA	9.73	-.37	.01
	Preference for STR by SOL x REA	10.50	.57	.01
	Object-Number by STR x REA	9.98	.48	.01
	Word Pairs by REA	8.61	-.20	.01
	Word Pairs by STR x SOL	7.84	.20	.01
		(330)[2]		(.57)[3]
True-False-? Retention Test	Vocabulary	132.88	.20	.20
	Attitude-Toward-Ecology	29.91	.07	.04
	True-False-? Pretest	52.33	.32	.08
	Preference for Reacting	7.61	.06	.01
	Object-Number	11.59	.23	.02
	Groups of Words by STR x SOL x REA	11.23	.12	.02
	Sex by STR x REA	9.88	.33	.01
		(329)[2]		(.51)[3]

[1]The critical value is ${}_{.01}F_{(1,\infty)} = 6.63$.

[2]Degrees of freedom for residual.

[3]Total amount of variance explained by full model, including terms not achieving statistical significance according to the .01 criterion.

Several features dominate the results of these analyses. First, for all analyses of post and retention dependent variables, most of the variation accounted for by all predictors generally is due to student aptitudes, namely, vocabulary, word pairs, or attitude-toward-ecology pretest. Other categories of predictors (i.e., treatment effects, teacher effects, and ATI) are not major determinants of variation in the dependent variables.

A second significant finding is that, for most dependent variables, treatment effects did not account for as much variance as ATI effects. In other words, it seems that more variation can be explained by how teaching methods interact with student aptitudes than the main and interaction effects of treatments alone account for.

A third important finding from these analyses is that the aptitude, teacher, treatment, and ATI terms examined in this study generally were able to account for one-half or less of the total amount of variation in dependent variables that could be theoretically predicted, within the limits determined by the reliability of the dependent variables. This suggests that there are major contributors to variation in student achievement or attitude other than those identified in this research. Considerable attention should be directed toward identifying those "unknown" influences.

Given the nearly complete absence of previous ATI research on teaching effectiveness, it is probably best not to attach substantive explanations to the ATI terms which were observed. Such "explanations" would be speculations based on intuition rather than empirical relationships having a basis in defensible theory. It is better to be content with the descriptive character of these analyses showing that ATI terms do influence student achievement, but in a minor way relative to student aptitudes. This set of analyses, then, indicates that ATI should be considered in research on teaching and can provide some basis for generating more direct hypotheses to be tested in later studies. For further examination of this area and for a review of pertinent literature, the reader should examine the dissertation by Winne (1976).

Path Analyses of Treatments and Student Perceptions

It is reasonable to expect that individual students perceive teachers differently, and that these variations in perception may limit or enhance the effects of teacher behavior on student achievement. Thus it was hypothesized as part of the present experiment that student perceptions of structuring, soliciting, and reacting (as measured by student ratings of teacher behavior) would mediate the effects of these variables on student achievement.

An explanatory "path" model (shown in Figure 9) specifies the hypothesized sequence of effects.

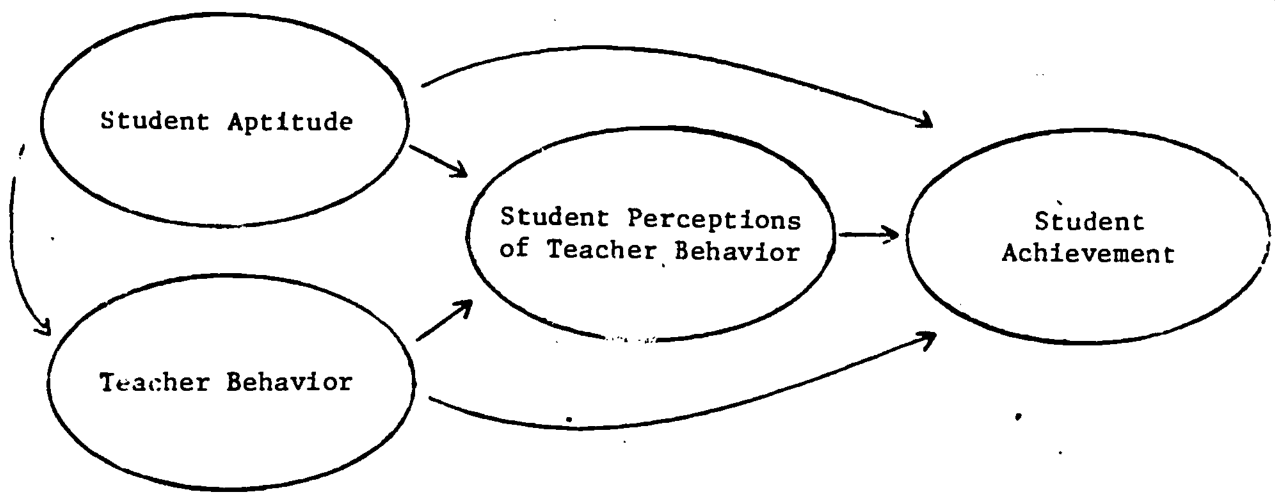


Fig. 9. Hypothesized sequence of effects in the path model.

The model assumes a loose, causal ordering of the variables in chronological sequence. To test the hypothesized flow of effects, the study employed path analysis, which determines the direct and indirect effects of several variables on other variables within a closed system.

> The method of path coefficients is not intended to accomplish the impossible task of deducing causal relations from the values of the correlation coefficients. It is intended to combine the quantitative information given by the correlations with such qualitative information as may be at hand on causal relations to give a quantitative interpretation [Wright, 1934, p. 193].

Path coefficients were in turn defined as follows:

> The fraction of the standard deviation of the dependent variables (with the appropriate sign) for which the designated factor is directly responsible, in the sense of the fraction which would be found if this factor varies to the same extent as in the observed data while all others (including the residual factors...) are constant [ibid. p. 162].

In the present model, the student aptitude and teacher behavior variables are exogenous--or outside the control of the system; they are considered "givens." Each of these exogenous variables was hypothesized to have a causal effect on student perceptions and student achievement. In a path model, the causal flow always moves in the direction of the arrows. Thus, while student perceptions may be a cause of student achievement, student achievement cannot, in this model, be a cause of student perceptions.

The path analysis addresses the major question of the explanatory value of two alternative paths. The first path leads directly from teacher behavior to student achievement. The relative magnitude of this path coefficient will indicate the direct effects of teacher behavior on student achievement. The second path leads from teacher behavior to student perceptions and then to student achievement. Comparing the size of the coefficients of the direct and indirect paths answers the question whether student perceptions of teacher behavior mediate the effects of teacher behavior on student achievement.

Instrumentation and data analysis procedures. As described previously, actual teacher behavior was measured by trained observers' frequency counts. The amount of structuring behavior was measured for each half-class by averaging over the nine lessons the number of 10-second intervals in which structuring behavior was observed. The amount of soliciting was the proportion obtained when the number of 10-second intervals devoted to higher-order questions was divided by the number of 10-second intervals devoted to either higher- or lower-order questions. This proportion for each lesson was averaged over lessons to obtain the measure of soliciting for each class. The amount of reacting was the proportion obtained when the number of 10-second intervals devoted to high-reacting behavior was divided by the number of 10-second intervals devoted to either high-reacting or low-reacting behavior. This proportion was also averaged over lessons.

The instrument used to measure student perceptions of teacher behavior was the Treatment Perception Scale (TPS). The right-hand column of Table 81 lists the items of the TPS used to measure student perceptions

TABLE 81

Specific Teacher Behaviors Corresponding to Items on the Treatment Perception Scale

Treatment Variations	TPS Items
The Structuring dimension consisted of:	
outlining the lesson content;	*Doesn't tell me exactly what I'm supposed to learn.
stating objectives at the beginning of a lesson;	Tells me what is really important to learn.
reviewing the main ideas and facts covered in a lesson;	
signaling transitions between parts of a lesson;	*Keeps me guessing about what we're going to talk about next.
indicating important points in a lesson;	Goes over important things at the end of each day's lesson.
summarizing the parts of the lesson as the lesson proceeded;	Ties together ideas during the lesson.
The Soliciting dimension consisted of:	
higher-order questions that required the students to do more than simply recall information (asking students to combine facts to form principles, compare or contrast, interpret, or evaluate are typical examples of high soliciting); and...	Asks questions that really make me think.
lower-order questions requiring students simply to recall information.	*Asks questions only about things I've read.
The Reacting dimension consisted of:	
the following high-reacting behaviors...	
praising correct responses;	Says things like "Great!" when I answer questions correctly.
providing reasons when a student response was judged to be incorrect;	Tells us why wrong answers are wrong.
prompting by providing a hint when a student response was incorrect or incomplete;	Gives me a hint when the answer to a question isn't exactly right.
writing correct student responses on the chalkboard;	

Treatment Variations	TPS Items
and the following low-reacting behaviors...	
using neutral feedback (e.g., "OK," "Uh huh") after correct student responses;	*Says nothing besides "No" when I give a wrong answer.
not providing reasons when a student response was judged to be incorrect;	
probing by asking a student to continue or elaborate a response.	

*Responses to these items were reversed for scoring purposes.

of teacher behavior opposite to the definitions of the teacher behavior to which they were keyed. To compute TPS subscale scores for structuring, soliciting, and reacting, the pupil responses to the items were summed, and then averaged for the half-class. Reliability coefficients of the half-class means for the TPS subscales are shown in Table 82.

Results of the path analyses. Table 83 shows the means, standard deviations, and intercorrelations of the half-class mean scores for each variable.

Since the three teacher behaviors--structuring, soliciting, and reacting--were manipulated independently, separate path analyses for each of these behaviors were considered appropriate. Figure 10 presents the path model for the structuring behavior. As indicated, the numbers in parentheses are the zero-order product-moment coefficients; the other numbers are path coefficients, or standardized partial regression coefficients. These path coefficients were obtained by computing multiple regression equations in which the dependent variable was, in turn, (a) student achievement, with teacher behavior, student perception, and student vocabulary as the independent variables; (b) student perception, with teacher behavior and student vocabulary as the independent variables; and (c) teacher behavior, with student vocabulary as the independent variable.

Of major interest is the direct path from teacher structuring behavior to student achievement. The zero-order correlation of .32 shows that the two variables are positively correlated. But the path coefficient, which represents the direct effect of teacher structuring on student achievement, is only .04. Something else is contributing to the moderate positive correlation of .32.

Table 84 shows the decomposition of the zero-order correlations in Figure 10. The r_{xy} column contains the zero-order correlations, each of which equals the sum of causal and noncausal effects.

Causal effects are the effects that follow the direction of the arrows. For example, teacher behavior affects student achievement, not vice versa. Noncausal effects are the effects that go in the direction opposite to that of the arrows. For example, the path from teacher

TABLE 82

Reliability[1] (within half-class consistency) of the Subscales on the Treatment Perception Scale

Subscale	Reliability
Perceived Structuring Subscale	.786
Perceived Soliciting Subscale	.511
Perceived Reacting Subscale	.832

[1]See Cronbach et al., 1972, pp. 74-84.

TABLE 83

Means, Standard Deviations, and Intercorrelations of the Variables in the Path Models (N = 32 half-classes)

Variable	Mean	SD	Correlation Matrix						
			2	3	4	5	6	7	8
1. Vocabulary	21.23	2.49	.74	.42	.25	.20	.25	.12	.01
2. Multiple-Choice Posttest	20.45	2.26		.50	.11	.34	.32	-.28	.11
3. Perceived Structuring	19.50	1.88			.08	.48	.56	-.11	.21
4. Perceived Soliciting	6.05	0.52				-.10	.28	.26	-.22
5. Perceived Reacting	15.14	2.25					-.11	-.22	.75
6. Observed Structuring	28.91	28.78						-.04	-.02
7. Observed Soliciting	0.37	0.26							-.14
8. Observed Reacting	0.45	0.42							

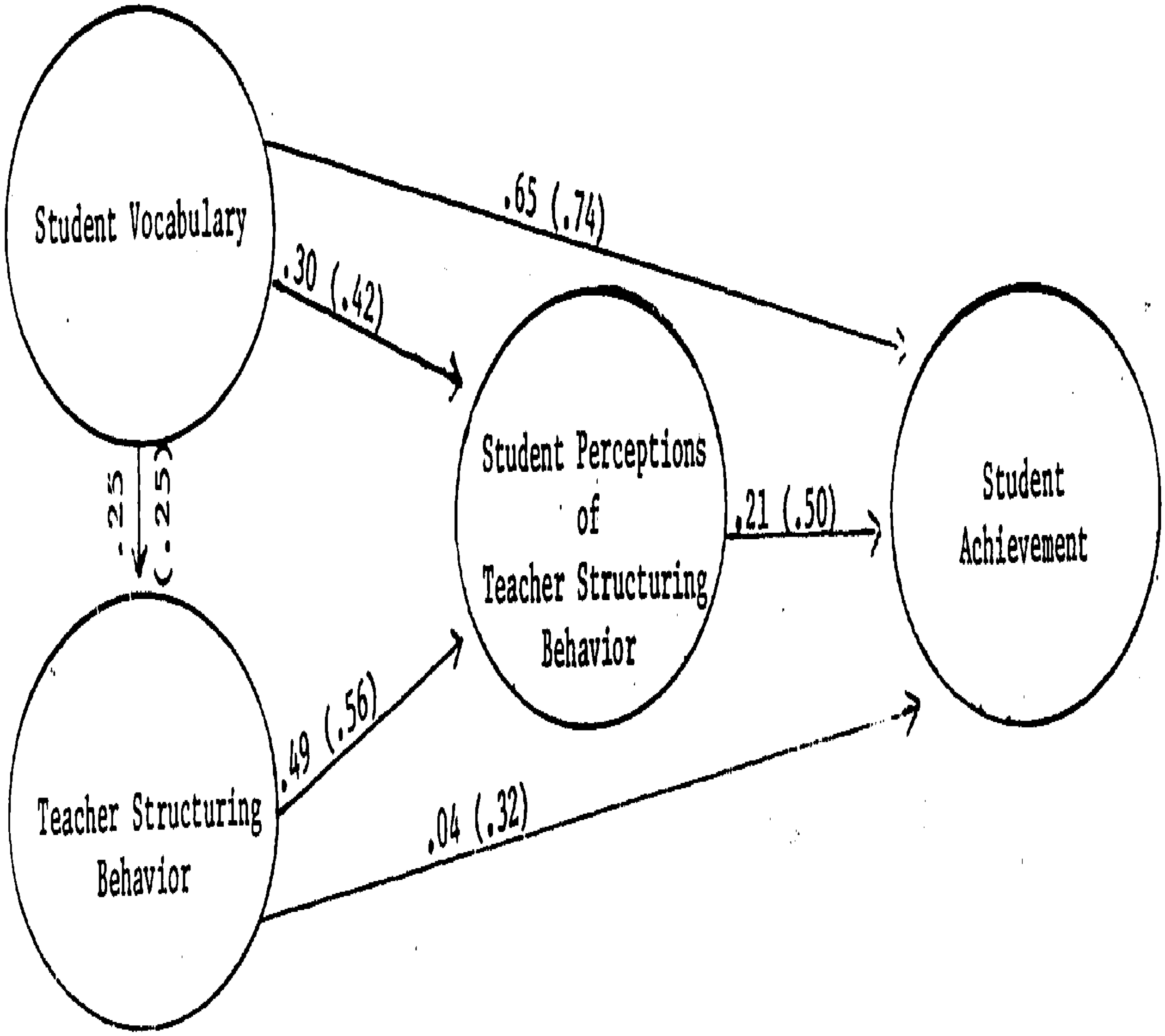


Fig. 10. Path diagram of teacher structuring behavior. Numbers in parentheses indicate zero-order correlations. Other numbers are path coefficients.

behavior through student vocabulary to student achievement is considered a noncausal effect of teacher behavior on student achievement, because teacher behavior is not considered a cause of student vocabulary in this model. Causal effects are further subdivided into direct and indirect effects. A direct effect is reflected in the path coefficient leading directly from one component of the model to another component. An indirect effect is the product of the path coefficients that lead from one component through one or more other components to the final component.

TABLE 84

Decomposition of the Zero-Order Correlations in the Structuring Behavior Model

Pairs of Variables		r_{xy}	Causal Effects: Direct Effect	Causal Effects: Total Indirect Effects	Causal Effects: Total Causal Effects	Noncausal Effects
1 Vocabulary	2 Observed Structuring	.25	.25	none	.25	none
1 Vocabulary	3 Perceived Structuring	.42	.30	.12	.42	none
2 Observed Structuring	3 Perceived Structuring	.56	.49	none	.49	.07
1 Vocabulary	4 Multiple-Choice Posttest	.74	.65	.09	.74	none
2 Observed Structuring	4 Multiple-Choice Posttest	.32	.04	.10	.14	.18
3 Perceived Structuring	4 Multiple-Choice Posttest	.50	.21	none	.21	.29

For the correlation of .32 between teacher structuring behavior and student achievement, the direct causal effect is .04, the indirect causal effect is .10, and the noncausal effect is .18. The magnitude of the indirect effect indicates that teacher behavior positively influenced student perceptions and that student perceptions positively influenced student achievement. This result can be interpreted as indicating that teacher structuring behavior was mediated by students' perceptions in influencing student achievement. Thus, in the case of structuring behavior, the hypothesis was supported.

Figure 11 presents the path model for teacher soliciting behavior. The same conventions for distinguishing path coefficients from zero-order correlations are used here. The results show that the direct effect of teacher soliciting on student achievement is negative <u>and</u> greater than the zero-order correlation. The negative direction of the relationship indicates that a lower proportion of higher-order questions caused higher student achievement. The correlation coefficients are decomposed in Table 85.

The zero-order correlation of -.28 between soliciting behavior and student achievement results from (a) a direct path coefficient equal to -.38; (b) an indirect path coefficient (considering student perceptions as a mediating variable) equal to .03; and (c) a noncausal path coefficient equal to .07. The indirect path coefficient of .03 is essentially zero. Thus student perceptions of soliciting do not mediate the effects of teacher soliciting on student achievement.

Figure 12 presents the path model for teacher reacting behavior. Table 86 shows that the direct effect of teacher reacting on student achievement is negative (path coefficient = -.11). The indirect effect of teacher reacting on student achievement mediated by student perceptions is positive (path coefficient = .21). The path from teacher reacting to student perceptions of reacting is high and positive (path coefficient = .75), showing that students accurately perceived teacher reacting behavior. Finally, the path from student perceptions to student achievement is also positive (path coefficient = .28), indicating that students who perceived the teacher as using a higher proportion of high-reacting behaviors and greater achievement. For reacting we find that student perceptions of teacher behavior mediated the relationship between teacher reacting and student achievement. This finding is similar to that reported for teacher structuring. In both cases, the data support the hypothesis that student perceptions of teacher behavior would mediate the effects of teacher behavior on student achievement.

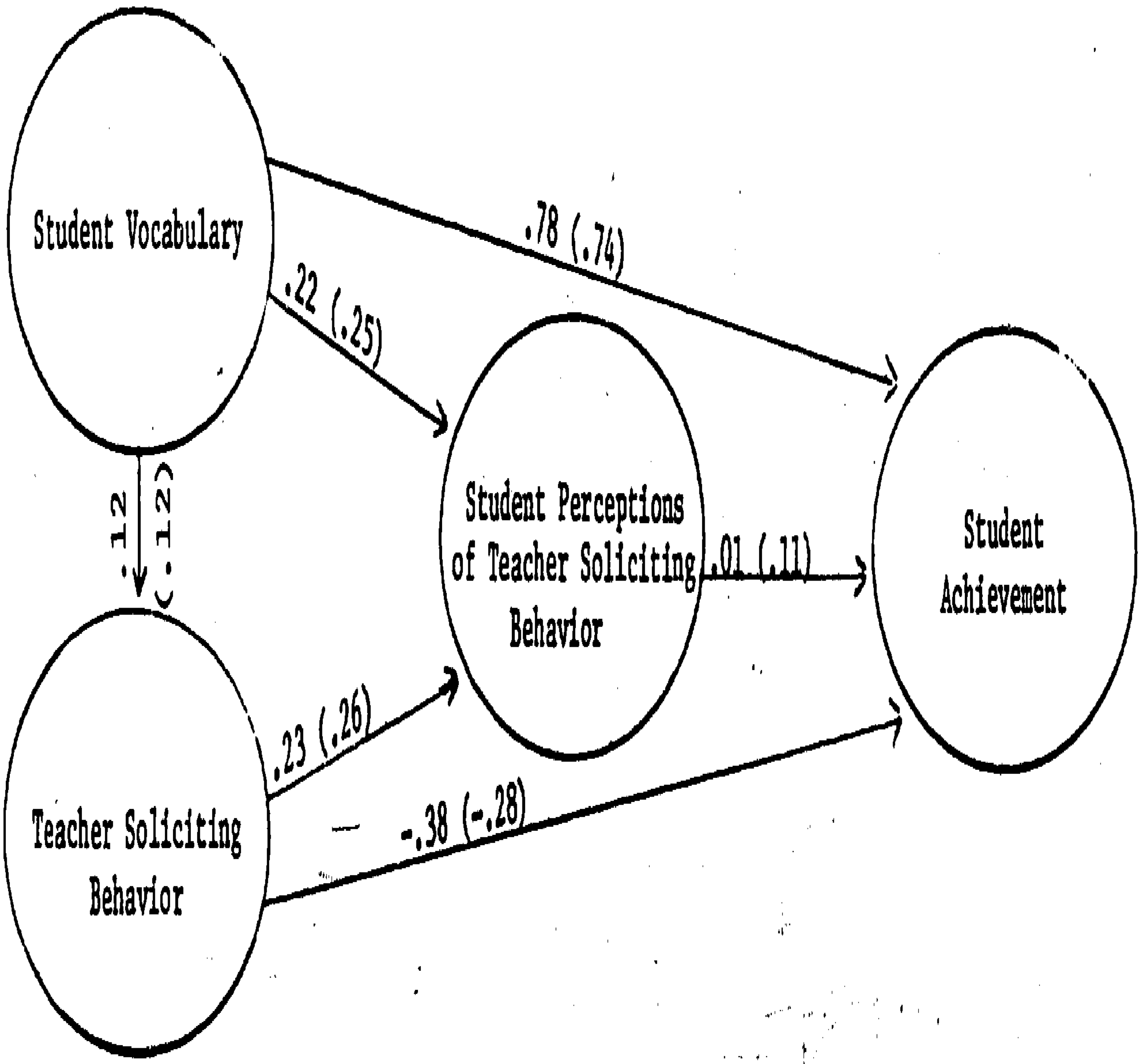


Fig. 11. Path diagram of teacher soliciting behavior. Numbers in parentheses indicate zero-order correlations. Other numbers are path coefficients.

222

221

TABLE 85

Decomposition of the Zero-Order Correlations in the Soliciting Behavior Model

Pairs of Variables		r_{xy}	Causal Effects: Direct Effect	Causal Effects: Total Indirect Effects	Causal Effects: Total Causal Effects	Non-causal Effects
1 Vocabulary	2 Observed Soliciting	.12	.12	none	.12	none
1 Vocabulary	3 Perceived Soliciting	.25	.22	.03	.25	none
2 Observed Soliciting	3 Perceived Soliciting	.26	.23	none	.23	.03
1 Vocabulary	4 Multiple-Choice Posttest	.74	.78	-.04	.74	none
2 Observed Soliciting	4 Multiple-Choice Posttest	-.28	-.38	.03	-.35	.07
3 Perceived Soliciting	4 Multiple-Choice Posttest	.11	.01	none	.01	.10

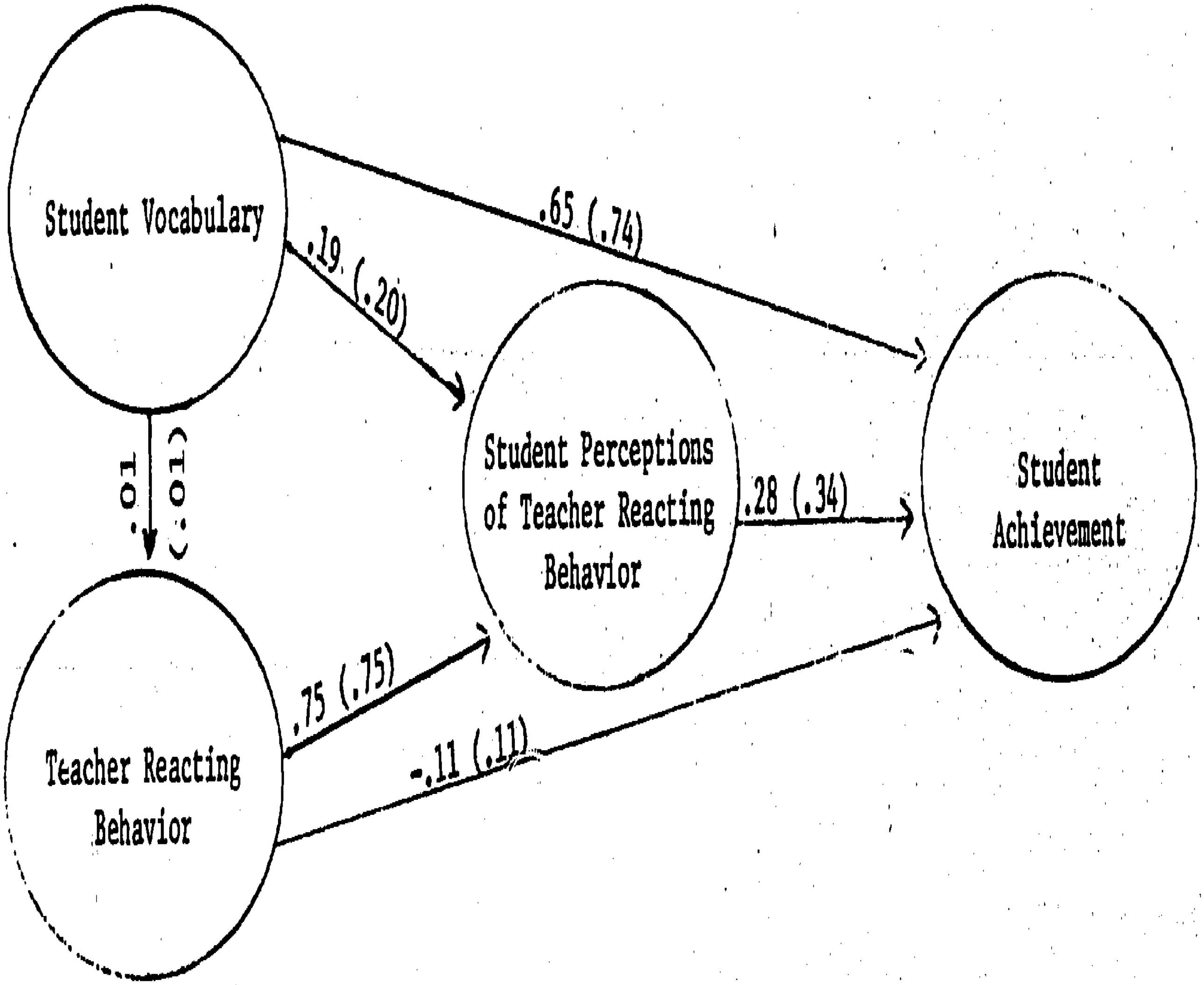


Fig. 12. Path diagram of teacher reacting behavior. Numbers in parentheses indicate zero-order correlations. Other numbers are path coefficients.

TABLE 86

Decomposition of the Zero-Order Correlations in the Reacting Behavior Model

Pairs of Variables		r_{xy}	Causal Effects: Direct Effect	Causal Effects: Total Indirect Effects	Causal Effects: Total Causal Effects	Noncausal Effects
1 Vocabulary	2 Observed Reacting	.01	.01	none	.01	none
1 Vocabulary	3 Perceived Reacting	.20	.19	.01	.20	none
2 Observed Reacting	3 Perceived Reacting	.75	.75	none	.75	.00
1 Vocabulary	4 Multiple-Choice Posttest	.74	.65	.09	.74	none
2 Observed Reacting	4 Multiple-Choice Posttest	.11	-.11	.21	.10	.01
3 Perceived Reacting	3 Multiple-Choice Posttest	.34	.28	none	.28	.06

In short, the results of the three path analyses suggest that the mediating effect of student perceptions is behavior-specific. For structuring and reacting, it seems that such perceptions do act as mediating variables, but this is not the case for soliciting.

The results of the primary analyses for this experiment showed few structuring or reacting main effects on the achievement posttests, but showed many significant main effects for soliciting. The path analyses confirm these findings and help to explain the nonsignificant structuring and reacting results. Perhaps the analyses of covariance for structuring and reacting were not significant because they did not include student perceptions. When student perceptions were included as variables mediating the effects of teacher behavior on student achievement, structuring and reacting effects did become evident. Thus, soliciting was not perceived very accurately (direct effect = .23); nonetheless, it affected achievement (direct effect = -.38). Structuring and reacting, on the other hand, were relatively accurately perceived (direct effects = .49 and .75, respectively), and did not affect achievement directly but affected achievement in large degree only to the extent that they were perceived (indirect effects = .10 and .21, respectively).

These analyses point to the importance of assessing student perceptions of teacher behavior and other possible mediating variables when examining relationships between teacher behavior and student achievement. Path analysis provides a useful technique for this purpose.

Chapter IV. SUMMARY, CONCLUSIONS, AND IMPLICATIONS

This chapter provides a summary of the purposes, methods, and main results of the present experiment. Then it presents statements concerning conclusions and implications for research on teaching, for teacher education, and for teaching itself.

Summary

The classroom recitation strategy of teaching is extremely widespread, and variables within that strategy have been subjected to more research than those of any other. Most research on classroom recitation variables has, however, consisted of correlational studies. Further, the few experiments have dealt with only one independent variable at a time. Correlational studies make causal inferences questionable, and single-factor experiments fail to do justice to the complexity of teaching. The present experiment was accordingly intended to determine the causal efficacy of several major variables within that strategy. More specifically, a factorial design was used to determine both the main effects and the interaction effects of three major composite variables--structuring, soliciting, and reacting--in the classroom recitation.

Four experienced teachers were trained to use eight variations of the recitation strategy. These eight variations differed in the level (high or low) of structuring, soliciting, and reacting manifested by the teacher. The high and low levels of each of these factors were defined in terms of teaching behaviors that, on the basis of earlier correlational research, were considered possible determiners of student achievement.

High structuring consisted of reviewing, stating objectives, outlining the lesson, signaling transitions, indicating important points, and summarizing. Low structuring was defined as the absence of these behaviors. High soliciting consisted of asking questions of which approximately 60 percent were higher-order questions and 40 percent were lower-order questions and waiting a relatively long time (three seconds or more) after a student's response before calling on a second student. Low soliciting consisted of asking questions of which approximately 15 percent were higher-order questions and 85 percent were lower-order questions and waiting a short time (less than three seconds). High reacting consisted of praising correct responses, providing reasons for wrong answers, prompting, and writing student ideas on the board. Low reacting consisted of using neutral feedback after correct student responses, not providing reasons for wrong answers, and probing.

The experiment was conducted in sixth-grade public school classrooms. The students in 12 such classrooms were randomly divided into two groups, and eight other groups were formed by eliminating fifth graders from mixed fifth-sixth grade classes. Each of the resulting 32 half-classes had 13 students on the average. Each group was taught by one of the four trained teachers using one of the eight variations. A specially prepared two-week curriculum on ecology was taught.

Before the first day of teaching, the students took several pretests: a vocabulary test, four memory tests, a true-false-? test of knowledge of ecology, an inventory of interest in ecology, and an inventory of preferences for teaching styles. Then the ecology lessons were taught for about 40 minutes per day for nine days. During the first five minutes of each lesson, the students read two to four pages of text on ecology. The remainder of the lesson was devoted to classroom recitation, with the teacher structuring and soliciting, the students responding, and the teacher reacting. The teacher referred continually to a detailed lesson plan that served almost as a script operationally defining each of the variations.

After nine days of instruction, the students took multiple-choice and essay tests of their knowledge and understanding of ecology, a questionnaire on their attitudes toward ecology, a treatment perception scale, and a teacher characteristics scale. Three weeks later, the students were given the same multiple-choice and essay tests to measure retention. Also, at this time, the students again took the true-false-? test on ecology and the attitude inventory.

Observational data indicated that the teachers succeeded in performing the recitation strategy in close accordance with each of the eight factorially designed variations intended. To determine whether the variations had different effects on student achievement and attitude, analyses of covariance were performed, with vocabulary test or initial attitude scores as the covariate. The unit of analysis was both the half-class, in some analyses, and the student, in others. Separate analyses were performed on the posttest and retention test scores. Separate scores on the multiple-choice achievement test were obtained for the students' responses to text-and-teacher-as-source items and to teacher-only-as-source items. These two categories of items were further classified into those that called for lower-order (recall) responses and higher-order (reasoning) responses.

A summary of the results in the form of the probability values of the variances resulting from different sources, is presented in Tables 87 and 88. With the half-class as the unit of analysis, the results for the posttests, given the day after teaching ended, indicated that the low-soliciting treatment resulted in higher achievement on the teacher-only-as-source items of both lower-order and higher-order types. The low-soliciting treatment was also more effective in bringing about achievement on the text-and-teacher-as-source items of the lower-order type. High structuring was more effective (but only at the .11 level) in bringing about achievement on the teacher-only lower-order items. Structuring x interaction effects on posttest achievement on teacher-only higher-order items and on text-and-teacher lower-order items were found; the combination of low structuring and low reacting yielded lower posttest achievement on these two types of items. No significant effects were found for the essay achievement posttest and the attitude-toward-ecology posttest.

For the measures of retention obtained three weeks after the end of the teaching, several similar main and interaction effects were found. Again, the low-soliciting treatment yielded higher multiple-choice achievement test performance (at the .07 level) on the teacher-only-as-source lower-order questions. High structuring was more effective (the .01 level) in bringing about achievement on the same kind of items. High reacting was similarly more effective (at the .10 level) on these items. Thus, it could be inferred from these main effects that the most effective of the eight variations on these lower-order teacher-only-as-source items on the retention test was the high structuring-low soliciting-high reacting treatment. (The results in Table 49 show that this inference is close to the mark. The high struct ng-low soliciting-high reacting treatment barely misses yielding the highest of the eight adjusted means.)

TABLE 87

Probability Values Resulting from Analyses of Covariance with the Half-Class as the Unit of Analysis (N = 32)

Source	Posttests							Retention Tests						
	Multiple-Choice Achievement							Multiple-Choice Achievement						
	Total	Teacher Only, Lower-Order	Teacher Only, Higher-Order	Text & Teacher, Lower-Order	Text & Teacher Higher-Order	Essay (Log Transforma.)	Attitude toward Ecology	Total	Teacher Only, Lower-Order	Teacher Only, Higher-Order	Text & Teacher, Lower-Order	Text & Teacher Higher-Order	Essay (Log Transforma.)	Attitude toward Ecology
Structuring (STR)	-*	.11	-	-	-	-	-	.21	.01	-	-	-	-	-
Soliciting (SOL)	.01	.05	.05	.004	-	-	-	.13	.07	.22	.19	-	.28	-
Reacting (REA)	.26	-	.30	-	-	-	-	.11	.10	.15	-	.32	.02	-
STR x SOL	-	-	-	-	-	-	.17	-	.17	-	.29	-	-	-
STR x REA	.18	-	.09	.03	-	.25	.31	.04	.23	.06	.04	.26	-	-
SOL x REA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STR x SOL x REA	-	-	-	.22	-	-	-	-	-	-	-	-	-	-

*- means F < 1.00.

TABLE 88

Probability Values Resulting from Analyses of Covariance with the Student as the Unit of Analysis (N = 385)

Source	Posttests							Retention Tests						
	Multiple-Choice Achievement							Multiple-Choice Achievement						
	Total	Teacher Only, Lower-Order	Teacher Only, Higher-Order	Text & Teacher, Lower-Order	Text & Teacher Higher-Order	Essay (Log Transforma.)	Attitude toward Ecology	Total	Teacher Only, Lower-Order	Teacher Only, Higher Order	Text & Teacher, Lower-Order	Text & Teacher Higher-Order	Essay (Log Transforma.)	Attitude toward Ecology
Structuring (STR)	.19	.09	-*	-	-	-	-	.21	.04	-	-	.06	-	-
Soliciting (SOL)	.01	.04	.18	.03	-	.33	-	.29	.32	-	.31	-	.18	-
Reacting (REA)	-	-	-	-	.37	-	-	.05	.17	.36	.30	.16	.03	-
Teacher (TCHR)	.09	.02	.30	-	-	.03	-	.01	.22	.001	.11	.11	-	-
STR x SOL	-	-	-	-	-	-	.30	-	.30	-	.31	-	.35	-
STR x REA	.32	-	.02	.30	-	.23	.08	.07	.25	.03	.05	-	-	.30
STR x TCHR	-	-	.07	-	-	.03	.003	.25	-	.39	.08	-	.03	.01
SOL x REA	-	-	-	.35	-	-	-	.06	.37	.27	-	-	-	-

(continued)

TABLE 88 (Continued)

Source	Posttests							Retention Tests						
	Multiple-Choice Achievement							Multiple-Choice Achievement						
	Total	Teacher Only, Lower-Order	Teacher Only, Higher-Order	Text & Teacher, Lower-Order	Text & Teacher Higher-Order	Essay (Log Trans-forma.)	Atti-tude toward Ecology	Total	Teacher Only, Lower-Order	Teacher Only, Higher Order	Text & Teacher, Lower-Order	Text & Teacher Higher-Order	Essay (Log Trans-forma.)	Atti-tude toward Ecology
SOL x TCHR	-	-	.10	-	-	-	.28	.07	.11	-	.10	.17	.13	-
REA x TCHR	.10	.11	.12	.03	-	.04	.13	-	-	.03	-	-	-	-
STR x SOL x REA	-	-	-	.03	-	-	-	-	-	.32	-	-	-	-
STR x SOL x TCHR	-	-	.36	-	.23	.02	.16	-	.29	-	-	-	.09	-
STR x REA x TCHR	-	.12	-	.20	.36	.10	-	-	-	-	-	.14	.002	-
SOL x REA x TCHR	-	.34	-	.38	-	.08	.09	-	-	-	.22	-	.21	.33
STR x SOL x REA x TCHR	.11	.37	-	-	.003	.01	.09	.01	.27	-	.05	.001	.001	.17

*- means F < 1.00.

The structuring x reacting interaction effect was significant for two of the retention test subscales: teacher-only higher-order questions and text-and-teacher lower-order questions. Of the four combinations, the low structuring-low reacting treatment was the least effective. On the essay retention test, the high-reacting treatment was significantly more effective. There were no significant main or interaction effects on the attitude-toward-ecology retention scores.

When the analyses were performed with the student as the unit of analysis, it was possible to examine the differences attributable to the four teachers as sources of variance. These differences were statistically significant despite the relatively high degree of control of teacher behavior and subject matter. These teacher effects appeared both as main effects and as interactions with the various treatment variables in such a way that the latter had different effects depending on which teacher was considered. The main effects of the teachers and their interaction effects with the treatment variables suggested that aspects of teacher behavior and characteristics, uncontrolled and unmeasured in this investigation, were operating so as to influence student achievement and attitude.

Path analysis was used to determine the degree to which students' perceptions of the teaching mediated the effects of the treatments on achievement. The results indicated that such perceptions did mediate the effects of the structuring and reacting variations but not those of the soliciting variation.

To investigate the extent to which students could achieve the objectives of the ecology curriculum from merely reading the written materials, another study was conducted a year later. In this study, students in a sample of three comparable classrooms merely read the ecology curriculum and took the posttests and retention tests. Results of this investigation support the conclusion that teaching contributed significantly and substantially to student achievement beyond what occurred from merely reading the materials.

A generalized regression analysis was conducted to explore for the occurrence of aptitude-treatment interactions (ATI). The results indicate that ATIs accounted for approximately as much variation in student achievement as did treatment effects. These ATIs suggest, of course, that teaching behaviors interact with student traits, so that no single teaching method is best for all students.

The regression analyses also indicated that the teacher behaviors manipulated in this experiment accounted for only minor percentages of the variance in student achievement. In this respect, the experiment fell far short of disproving the conclusions concerning the importance of teacher variables that have emerged from the input-output studies considered in Chapter I. As was noted in that chapter, these input-output studies could not do justice to teacher variables because they have used teacher characteristics rather than teacher behavior as the independent variables, because they have used dependent variables consisting of pupil vocabulary rather than measures of pupil achievement of objectives at which instruction was explicitly aimed, and because they have used correlational methods that make causal inferences hazardous. The present experiment was intended to be invulnerable to all three of these criticisms. It used teacher behaviors suggested by previous correlational studies as the independent variables, it used measures of achievement of objectives at which instruction was explicitly aimed, and it was a true experiment in which the independent variables were manipulated and subjects (half-classes) were randomly assigned to different levels of the independent variables. Nonetheless, the teacher behavior variables did not account for any appreciably greater amount of variance in pupil achievement than has been found in the input-output studies. Thus, the present results cannot be regarded as disputing the conclusions that teacher behavior variables, of the kinds studied thus far, are relatively weak determiners of pupil achievement.

Conclusions

The four trained teachers were able to vary their instructional performances with high precision. Observational data indicated that the teachers, who taught as many as four different variations of the same lesson in a single day, made accurate transitions between substantially different treatment variations with no apparent difficulty. Thus, experienced teachers can be trained, and induced with the aid of script-like lesson plans, to behave both flexibly and precisely in implementing a complex teaching strategy. Observers' impressions indicated that none of the eight variations seemed bizarre or unlike what might go on in any classroom. It seems plausible that all eight variations occur in American classrooms.

Low soliciting, that is, asking questions of which only about 15 percent were higher-order, or reasoning, questions, was more effective in inducing achievement on both lower-order and higher-order achievement test questions for which only the teacher served as the source of information. Further, high structuring and high reacting also proved to be more effective. In short, in this experiment, the best treatment for bringing about achievement was the high structuring-low soliciting-high reacting variation.

Despite the rigorous control of content and teaching behavior, the four teachers had significantly different effects on student achievement. Hence, even in experiments, individual differences among teachers in style and temperamental factors should be measured to throw light on the determiners of such between-teacher variance in student achievement. Finally, the present experiment demonstrates that complex yet well-controlled experiments on teaching can be conducted in regular schools. This demonstration makes it more likely that future experimental findings, since they depend on operational definitions of variations in teaching and yield relatively unambiguous knowledge concerning causal connections, can be translated into forms that will be more immediately useful to classroom teachers in the real world of the schools.

Implications

An experiment of the kind reported here can have different implications for different audiences. The present study has implications for researchers, teacher educators, and teachers.

Implications for Researchers

The conclusions concerning the small amount of variance in achievement and attitude for which the teacher behaviors accounted can be considered to have two alternative implications for research workers. They could imply that the search for teacher behaviors that substantially influence pupil achievement and attitude is indeed forlorn. Assuming this to be true, researchers should therefore abandon this kind of enterprise. Although there may be dimensions of teachers and teaching that do make a substantial difference in student achievement and attitude, this position would imply that they do not lie in the realm of teacher behaviors. Perhaps overall strategies, such as mastery learning, personalized systems of instruction, or behavior-analytic approaches, may be necessary to account for substantially greater variance in student achievement and attitude. In any event, the present results point to the possibility that variations of teacher behavior within the classroom recitation strategy, as explained in this experiment and related correlational studies, make little difference.

On the other hand, there may yet be value in examining teacher behavior variables within the recitation strategy Other ways of defining and experimenting with such variables ought to be considered. In the following paragraphs, we consider implications concerning future research on the teacher behaviors investigated in the relatively large number of correlational studies and in the present experiment.

What does this experiment mean for such researchers? First, this study serves as one of the few demonstrations of what has been termed the descriptive-correlational-experimental loop. The first stage in this loop is the use of descriptive observations to define variables in teaching. The second stage is the examination of the potential causal efficacy of those variables through correlational research. The third stage is the testing of promising correlates through experiments that determine whether the variables cause differences in student achievement and attitude. The implication here is that future research on teaching should follow the present example and put promising variables to the test of experimentation.

Another implication for researchers bears upon the competing values of experimental control and representativeness. In the experiment reported here, the treatment variables and the conditions under which they were administered were controlled to a relatively high degree, as indicated by the data on fidelity of implementation. The four teachers were able to vary their instructional performance with high precision. On the representativeness side of the balance, observers' impressions indicated that none of the eight variations seemed highly unlike what might go on in any classroom. The experiment took place in public schools during the regular school day. The students were in the familiar surroundings of their own classroom.

But there were also threats to representativeness in the present design. The students in each class were randomly divided into two groups. Experimental teachers and classroom observers were introduced for a two-week period. The teaching was probably more intense and more highly structured than that to which the students were accustomed. The duration of the experimental teaching was relatively short, when compared to an entire semester or school year. There is no way of knowing how the results of this study would have differed if the balance between experimental control and representativeness had been different. Yet this balance is important in the design of experiments on teacher behavior--and it should be given careful thought early in the design of any experiment of this sort.

Another issue on which the present experiment throws light is the level of complexity of the independent variables to be tested. In the present experiment, teacher-behavior variables were put into three categories--structuring, soliciting, and reacting. Each of these manipulated variables contained from two to seven components. It would have been desirable, perhaps, to manipulate these components independently of one another. Such a procedure would have raised greatly the number of independent variables. The number would quickly have become greater than a full factorial design can feasibly handle within reasonable limits of sample size and teacher trainability. Even fractional factorial designs would permit using only about ten independent variables in a single experiment.

Accordingly, the present experiment illustrates the need for inevitably hazardous judgments and choices concerning the specificity or complexity of the independent variables. Specificity can be attained at the risk or working with relatively weak or trivial single behaviors. Complexity on the other hand carries the risk of combining specific behaviors into internally competing, or self-cancelling, clusters. At this point, only empirical evidence from experiments similar to the present one can serve as guides. For example, in another experiment, it might be desirable to manipulate independently several of the components of our present structuring variable, while soliciting and reacting variables are held constant. It might subsequently be desirable to do the same for the components of our present reacting variable, while structuring and soliciting are held constant. It may be significant in this connection that the one variable that had the largest, most significant, and most consistent effects in the present experiment was soliciting--the one variable of the three that was relatively specific and had only two components (wait-time and cognitive level of questions) as against the four or six components of the other two variables. Yet, even in soliciting, the effects may have been weakened by the possible opposition in effect of the two components, for longer wait-time (presumably desirable) was consistently joined together with higher-order questioning (which may have been the component that caused this treatment to be less effective in promoting achievement). In short, it may be desirable to perform experiments that depart from the present one in both directions, that is, in using both more specific or "purer" independent variables and also in using more complex, multifaceted independent variables.

In conducting such experiments, future research workers would do well to study differences in teacher style, intensity, and similar dimensions unobserved in the present study. Wider-ranging observation instruments should be employed to track down these variables. This means embedding correlational approaches within experiments. The present experiment would have yielded more useful information if the unexpected teacher effects could have been correlated with measures of the teacher's style, temperament, values, attitudes, and the like. Such variables need not be investigated merely through the usual personality or attitude inventory. They might be measured in the observed behavior of the teachers, such as rate of speech, amount of movement, types of managerial comments, and other aspects of teacher behavior that were unmanipulated and uncontrolled. In addition to trained observers, students can serve as sources of evidence of this kind by responding to low-inference questions concerning their teacher's behaviors, and the like. In the present experiment, such evidence from students was obtained along lines specifically related to the manipulated treatment variations. In future experiments, the net should be cast more widely to obtain information on additional teacher behaviors and characteristics. Thus, it will be possible through secondary analyses of the data from the present study to investigate some of these between-teacher differences by examining the within-treatment components of the variations. That is, within the structuring variable, how did the teachers differ in the relative proportions of the various components of structuring? And how did these differences relate to the differences between teachers in their effects on student achievement?

Further, it should be noted that, in the present experiment, the differences in student achievement attributable to the treatment variations and the teachers were more conspicuous for the teacher-only-as-source items of the multiple-choice achievement tests. These were items on material that was taught directly by the teacher and could not have been learned from the text material. The implication is that precise measurement of teaching effectiveness in terms of student achievement requires the construction of instruments that are sensitive to the teaching variables of interest and are not affected by other sources, such as text material read by the students.

It should also be noted that looking at the data from several perspectives proved enlightening. The ATI and path analyses added much to what was learned from the analyses of covariance.

Perhaps the most significant implication for research workers of the present experiment is that it was done. That is, it proved possible to depart from the correlational paradigm of most research on teaching in ways that proved not only feasible but productive of significant findings concerning the causal efficacy of teacher behavior variables in relation to student achievement. The present findings still must pass the test of replication before they can be taken seriously as bases for teacher education. Nonetheless, in demonstrating that an experimental basis for teacher education can be laid--a basis that uses manipulated teacher behavior where the fidelity of the manipulation has been verified in detail--the present study will, it is hoped, serve as an early and obviously improvable model of a promising approach to research on teaching.

Implications for Teacher Education

What does this study say to the field of teacher education? That field has in recent years turned increasingly to performance-based conceptions of its functions. The present investigation provides an example of one approach to the definition and validation of significant types of teacher performance. The operational definitions of the treatment variations used in this experiment illustrate what such performance-based objectives of teacher education could consist of.

Similarly, the kind of training used in this experiment to enable teachers to perform in specified ways has a bearing on techniques that could be used in performance-based teacher education. The training in this experiment depended heavily on the teachers' use of scripts that were specific to the material being taught and the behaviors being experimentally manipulated. It therefore does not indicate that teachers can or should be trained to behave with comparable precision in implementing various elements within a complex teaching strategy. It also does not indicate that the repertoire of teachers can be extended far beyond the normal range of approaches typically seen in classrooms. Whether teachers can be trained to behave in such ways without scripts remains to be seen.

Yet the present experiment does open the possibility that scripted training and performance may transfer to the real-life behavior of teachers. The effectiveness of the scripted training suggests that such training may provide a useful supplement to the microteaching, Minicourses, feedback of observations, and other devices that have already proven widely useful in teacher education.

Implications for Teaching

Finally, what does the present investigation mean for teachers and teaching? The strongest finding was that teachers who asked more lower-order questions--questions intended to elicit recall of information rather than complex applications or other kinds of information processing--and used shorter wait-times helped their students more in achieving and retaining knowledge and understanding of the subject matter. The same was true of teachers who did considerable structuring--stating objectives, outlining the lesson, emphasizing the important points, signaling transitions, and summarizing. And, the findings also favored high reacting--praising correct responses, providing reasons for judging a student response to be incorrect, prompting by providing a hint after an incorrect or incomplete response, and writing correct student responses on the chalkboard.

Beyond these immediate implications for teachers, there lies the general conception of specifying and understanding one's own behavior in the forms with which this experiment was concerned. The kinds of behavior here considered are neither costly nor, in all probability, dangerous. So teachers ought probably to feel free to try them on their own, even before the present findings are confirmed. In the long run, teaching is likely to get better as teachers become more aware of what they are doing and what difference it makes.

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APPENDIX A

OF

A FACTORIALLY DESIGNED EXPERIMENT ON

TEACHER STRUCTURING, SOLICITING, AND REACTING

November 1976

A NINE-LESSON UNIT ON ECOLOGY

Program on Teaching Effectiveness

Stanford Center for Research and Development in Teaching

WHAT IS ECOLOGY?

Imagine yourself on a walk through the foothills. Living things are all around you -- birds are flying here and there; squirrels chatter as they gather acorns and pine cones; some trees reach tall for the sun while shrubs squat over large parts of the ground. It's early spring. The warming sun begins to dry away last night's rain. Ants move back into their underground homes as the water seeps deeper into the earth or evaporates into the air. You glimpse a rabbit munching on some clover, but it scurries for cover when a hawk's shadow passes nearby.

"Neat! Look at that!" There are many beautiful and interesting sights. But did you ever wonder why you see the things you do? Why is it that squatting shrubs don't grow tall like the pine trees? Would you have seen the ants if it hadn't rained last night? What might have happened to the rabbit if there was too little rain for grass to grow?

You have been on an imaginary walk through the ecosystem of the foothills. But what is an ecosystem? The word can be broken down into two parts -- eco and system. "Eco" reminds you of a popular topic today -- ecology.

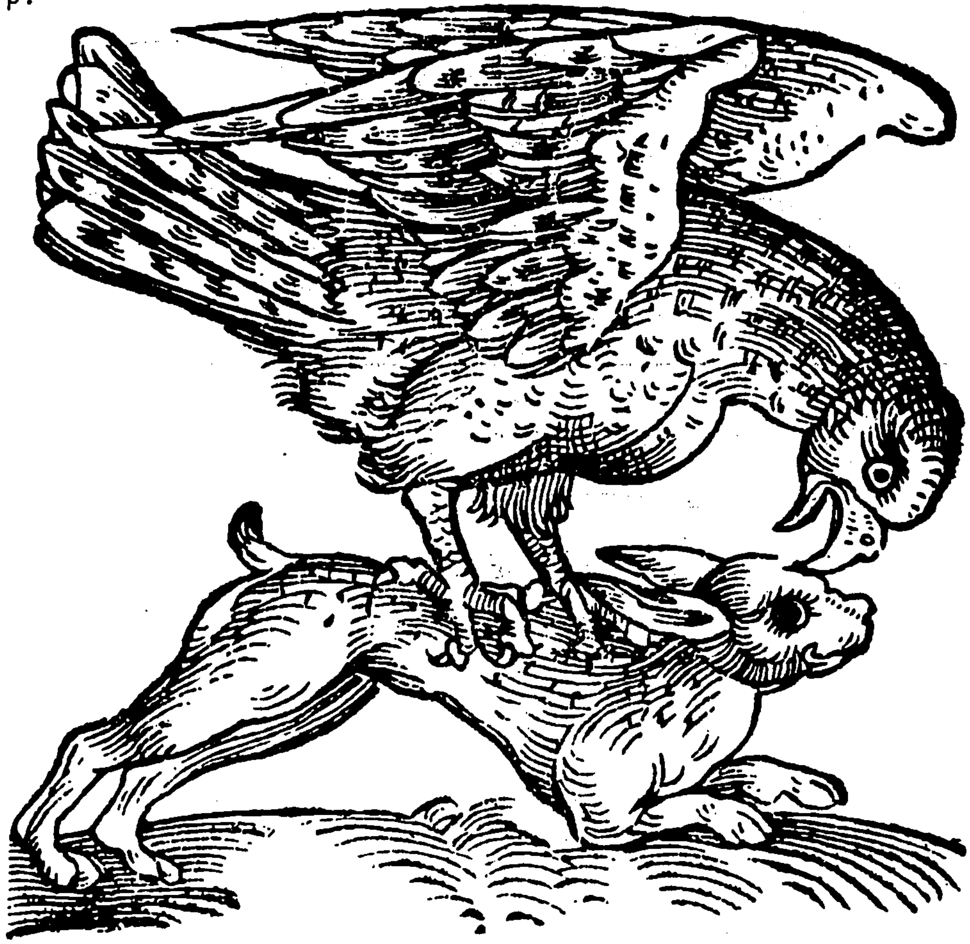
Ecology deals with plants, animals, people, and parts of the environment like soil, water, and wind. But is it more than just a collection of these different things? The "system" part of ecosystem gives us a hint. A system describes things that are arranged and related to one and the other. We have a muscle system that determines how we move, a system of traffic laws that tells us when to stop or turn right.

An ecosystem is a related collection of things like plants, animals, the weather, and humans. The rabbit depends on the clover for food. The clover needs rain to grow. The hawk depends on there being enough rabbits so it can have food. Here is a complex relationship between plants, weather, and animals.

Ecology is the name of the science which explores these kinds of relationships. Sometimes these relationships involve living things, like the clover and the rabbit. Other relationships between living things and non-living things, like the weather and the clover, are also important. In the next two weeks, you'll become an ecologist as you explore the ways living and non-living things are related in ecosystems.

Since the most important things in ecology are the relationships between living and non-living things, a good place to start our study of ecology is to name some kinds of relationships that we might find. We have already seen several of these relationships in our imaginary walk through the ecosystem. Let's look at them more closely to see what they are and how they are similar and dissimilar.

Imagine a rabbit sitting on a hillside munching grass. A hawk flies overhead, and its shadow passes over the rabbit. The rabbit gets frightened and scurries to its hole. The relationship between these two animals is common in nature: one animal becomes food to help the other animal live. We call this kind of relationship a predator-prey relationship. The rabbit is the hawk's prey. It must be killed to feed the predator, that is, the hawk. Can you think of other examples of a predator-prey relationship?



Another kind of relationship is important in ecology. Sometimes one living thing depends on another living thing for something but doesn't do it any harm. For example, many plants, like mistletoe, climb trees to get more sunlight. The mistletoe depends on the tree to help it live, but the relationship does no damage to the tree. We can label this a benefit-no difference relationship. Another example of a benefit-no difference relationship can be seen in the way grasses get a better supply of air when there are earthworms in the soil. By burrowing around the roots of the grass, earthworms leave passages for air to flow to the roots. The grass benefits at no expense to the earthworm.

You probably know that bees carry pollen on their legs as they travel from flower to flower. The flower needs pollen grains from other flowers to make seeds. The bee needs the nectar from the flower to make honey. Thus, as the bee feeds on the flower's nectar, its hairy legs pick up pollen. Then the bee flies off to another flower where the pollen falls off the bee's legs. This second flower can then make seeds. We could label this kind of relationship between the bee and the flower a mutual benefit relationship; the bee helps the flower by transferring pollen and the flower helps the bee by making nectar.

There are many different kinds of relationships between the living and the non-living things in an ecosystem. We have already seen how animals influence other animals, how plants and animals can cooperate, and how non-living things like the weather can affect living things. One of the jobs of an ecologist is to describe these relationships. By classifying the ways many different parts of the ecosystem relate to each other into types of relationships, the ecologist improves his understanding of how things work in an ecosystem. For example, we explored one example of a predator-prey relationship between rabbits and hawks. If an ecologist described the relationship between a woodpecker and insects that live in trees as a predator-prey relationship, you would understand he meant that the woodpecker eats the tree insects. The idea of a predator-prey relationship helps you understand how woodpeckers and tree insects are related in the environment.

As you begin to explore the science of ecology more thoroughly, you will discover other kinds of relationships. Each type of relationship will help you to describe and understand the way the ecosystem of the foothills is organized. And because these relationships are part of the science of ecology, they will be useful in understanding other kinds of ecosystems like the ecosystem of the ocean or the desert ecosystem.

ENERGY IN THE ECOSYSTEM

Living things in the ecosystem take part in many kinds of relationships. In each one of these relationships, living things have to do something. For example, to catch a rabbit for food a fox has to run after the rabbit. Even flowers are active because they are growing. How do these activities happen? What starts and keeps up activities is energy. Whenever there is activity, there is energy.

Energy is a very important idea in the science of ecology. If the fox had no energy, it couldn't chase the rabbit. In fact, it couldn't do anything! Because the energy that a fox or any other living thing has controls what it can do, it also controls the relationships between that living thing and its ecosystem. Therefore, energy is a big influence on the kinds of relationships that we find in an ecosystem. Let's look at this important idea further.

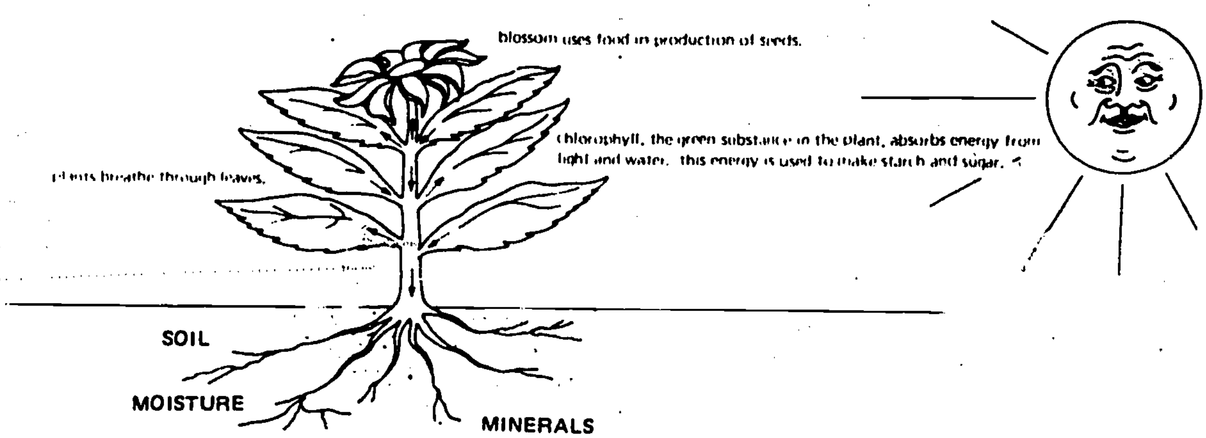
Whenever you see an activity, like running or growing, you can ask "Where did the energy come from?" One source of energy is food. For example, a glass of milk has about enough energy to keep you jogging for about half an hour. In the ecosystem of the foothills, there are lots of foods that supply energy. For example, the squirrel gets energy from eating acorns, walnuts, and pine seeds in pine cones. The birds eat insects to give them energy. In fact, all living things have some energy stored inside them. Even tree bark, which the deer eat, has energy stored in it!

But this seems to raise a question. Before we said that energy meant activity -- running, breathing, growing, for example. Each of these things involves movement, no matter how slow. A tree may seem hardly to move at all. But in the spring, when leaf buds start to turn into leaves, it certainly does move. Does the walnut that's fallen from the tree move before the squirrel eats it? No. It's just lying on the ground. But we know that it has energy stored in it, too, because when squirrels eat walnuts, they can be active -- run and breathe and grow.

It seems there are different kinds of energy. Some energy means activity and some energy means only that activity is possible sometime later. So, we have names for each kind of energy. Energy that we see in things that are active is called <u>kinetic energy</u>. The word kinetic comes from a Greek word for moving. The other kind of energy is stored in living things, like the energy in the walnut. There is a possibility or a potential for activity only if something happens, like when the walnut is changed to energy after it's eaten and digested. This kind of energy stored in the walnut is called potential energy. It is only a possibility that it will become kinetic energy. Something has to happen to it first.

So far, we have talked about eating food as one way to get energy. Birds eat insects, snakes eat mice, humans eat apples. Like animals, plants are sources of energy, too. But where do plants get their energy? Do plants "eat"?

Plants are a special kind of living thing. They don't eat anything that was living like animals do. Instead, plants are the only living things that make their own food! They do this by combining chemicals and sunlight to make sugar. All they need is a part of the air called carbon dioxide, some water, sunlight, and a special chemical called chlorophyll and -- poof -- sugar. The kind of chemical process plants use to make sugar has a special name -- photosynthesis.



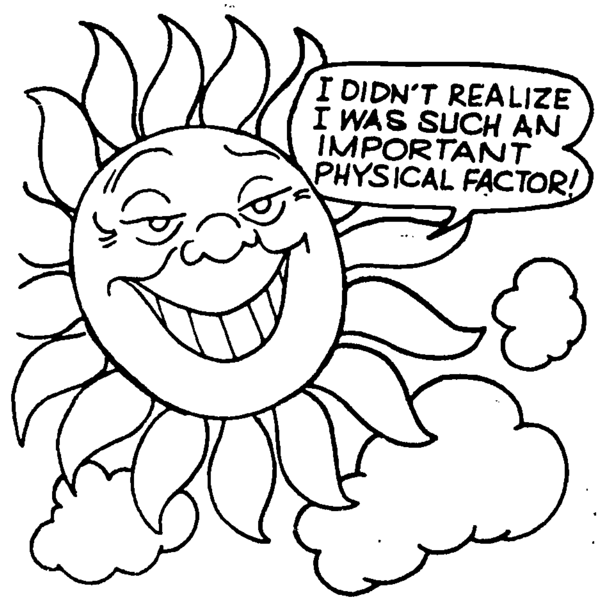
Sunlight is the energy source for photosynthesis in the complex system of the living plant.

Not all plants can photosynthesize to make sugar -- only green plants. In fact, the green color comes from the special chemical, chlorophyll. Mushrooms and other plants that aren't green usually live off green plants by "eating" the remains of green plants that have died.

Let's return to the importance of energy as a controller in the ecosystem. Plants are sources of energy for animals who eat the plants. Because animals eat plants, we call the animals consumers. Since plants make food rather than consume it, we call plants producers. So, we have a basic ecological relationship about energy in the ecosystem. Producers or plants make energy for the consumers, animals and non-green plants. Without the plant producers, the animal consumers wouldn't have energy -- they all would die. Therefore, things that affect the world of plants have a big influence on the world of animals. And, this whole relationship is based on how energy gets from one place to another -- from the plant producers to the animal consumers.

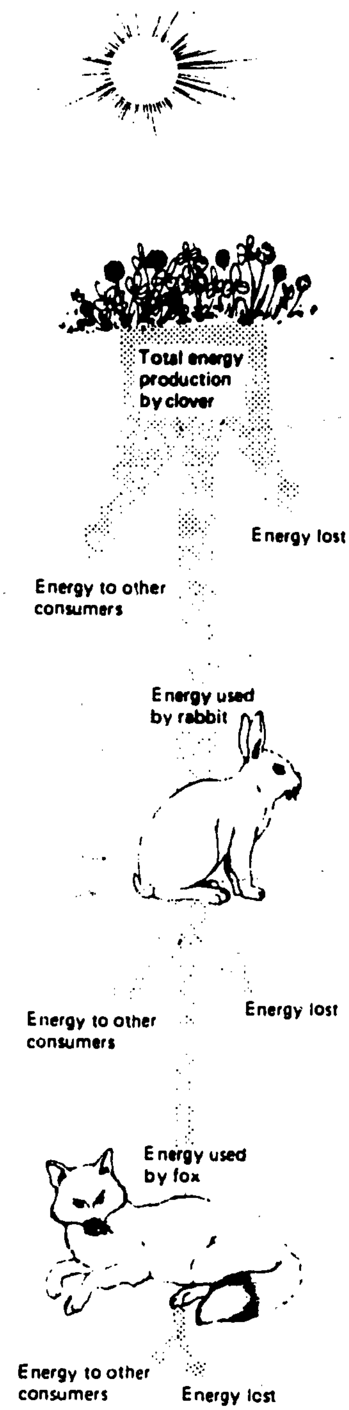
THE FLOW OF ENERGY IN THE ECOSYSTEM

Energy is an essential ingredient for life. Living things' need for energy influences many of the relationships in an ecosystem. One of the important things which ecologists study is how energy moves from one place in the ecosystem to another. For example, plants like clover use energy from the sun to make sugar. The sugar is stored in the plant. Later it becomes food for animals. But the useful energy that a rabbit gets by eating plant roots is less than all the useful energy the plant received from the sun. When a fox eats the rabbit, the amount of useful energy the fox gets is less than all the useful energy the rabbit had. Let's see why energy is lost at each of these points and what it means for the ecosystem.



Plants use energy from the sun in two ways. First, they make sugar and store it in their leaves, stems, and roots. This is how plants grow. Second, plants use energy to stay alive. This energy does not get stored. It is lost after it is used. Now, we can see that the energy stored in the plant is less than all the energy the plant received from the sun. This is because some of the sun's energy was used to keep the plant alive. But the energy that <u>was</u> stored by the plant can be used again by the plant to stay alive or by an animal which eats the plant.

Now let's see what happens to the energy a rabbit gets when it eats clover. The rabbit uses energy from the plants to make muscle, bone, and other living tissues. These body parts are places for energy. It also changes some energy from the plant into kinetic energy to stay alive. The rabbit walks around to get to other plants, breathes, sleeps, scratches, and does many other things. Each activity uses some energy. So, when the rabbit is eaten by a fox, the fox gets less energy than the rabbit got from eating the clover.



Now, the fox uses some energy to digest the body of the rabbit. It also uses energy to run, to reproduce, and so on. By the time something else eats the fox, there is even less energy that can be used for live activities.

In general, the movement or flow of energy through the ecosystem is like this example. The amount of <u>useful energy</u> gets smaller and smaller at each step in the energy flow. Since the rabbit is the first living thing to get energy from the producer plants, it's called a first-order consumer. Being second in line, the fox is called a second-order consumer. The next animal in line is a third-order consumer.

The way energy flows through the ecosystem involves a very important principle about energy. Energy that is useful to things in the ecosystem moves in only one direction -- from the sun to producers to first-order consumers to second-order consumers, and so on down the line. Energy never goes backwards in this flow.

MATTER IN THE LIVING WORLD

You've probably heard the word recycle many times. We talk about recycling aluminum cans, glass bottles, paper bags, and other things. What we mean by recycle is that we use the things over again -- returnable soda bottles are cleaned and filled with soda again and again. The same thing happens to all the natural materials in an ecosystem. In fact, materials are always recycled in nature. Let's look more closely at some of these materials and the way they are naturally recycled.

The Travels of Harvey Carbon

Meet Harvey Carbon -- he's a chemical substance that is essential for life. We see him best as coal. But he really gets around more in shapes harder to see than coal. Let's go with him on his adventures. We begin in the air.

Air is made up of lots of things -- oxygen, nitrogen, and other gases. Harvey started out as a gas called carbon dioxide. He hung around for awhile until an oak tree took him in through its leaves. Inside the leaves, he was mixed up with some other chemicals in the process of photosynthesis and became organic material. As a solid chemical compound, he was put to use in making seeds. In a few months he had a nice home inside a ripe acorn. So, for the first part of Harvey's travels in the ecosystem, we see him changing from a gas called carbon dioxide into an acorn.

Next, Harvey and his acorn fell off the oak tree's branches. A hungry squirrel happened along and snatched up the acorn for lunch. When the acorn was digested in the squirrel's stomach, Harvey Carbon moved into some of the fat the squirrel carried around. He stayed there for awhile until the squirrel died.

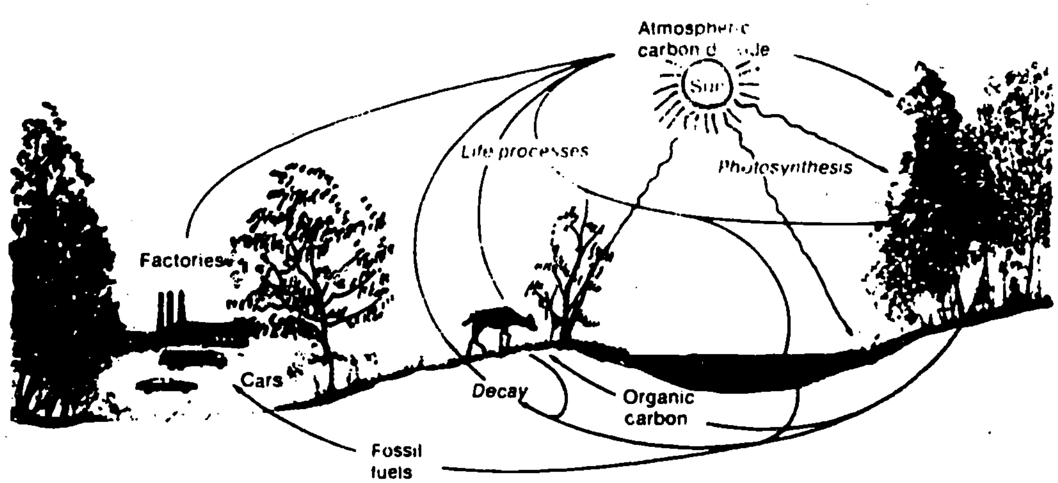
After the squirrel died, bacteria began to grow on its dead flesh. Some of the bacteria gave off gases that contained carbon dioxide. Harvey was part of these gases, and he became carbon dioxide in the air again.

As we can see, Harvey Carbon really travelled around -- from the air to the acorn to the squirrel and back again to the air. Now he's ready to be used again by a plant. Much like the soda bottle that is refilled over and over, Harvey Carbon has been recycled. But unlike the soda bottle which cannot be recycled if it's broken, Harvey Carbon is always usable in one form or another.

The Cycles for Other Materials

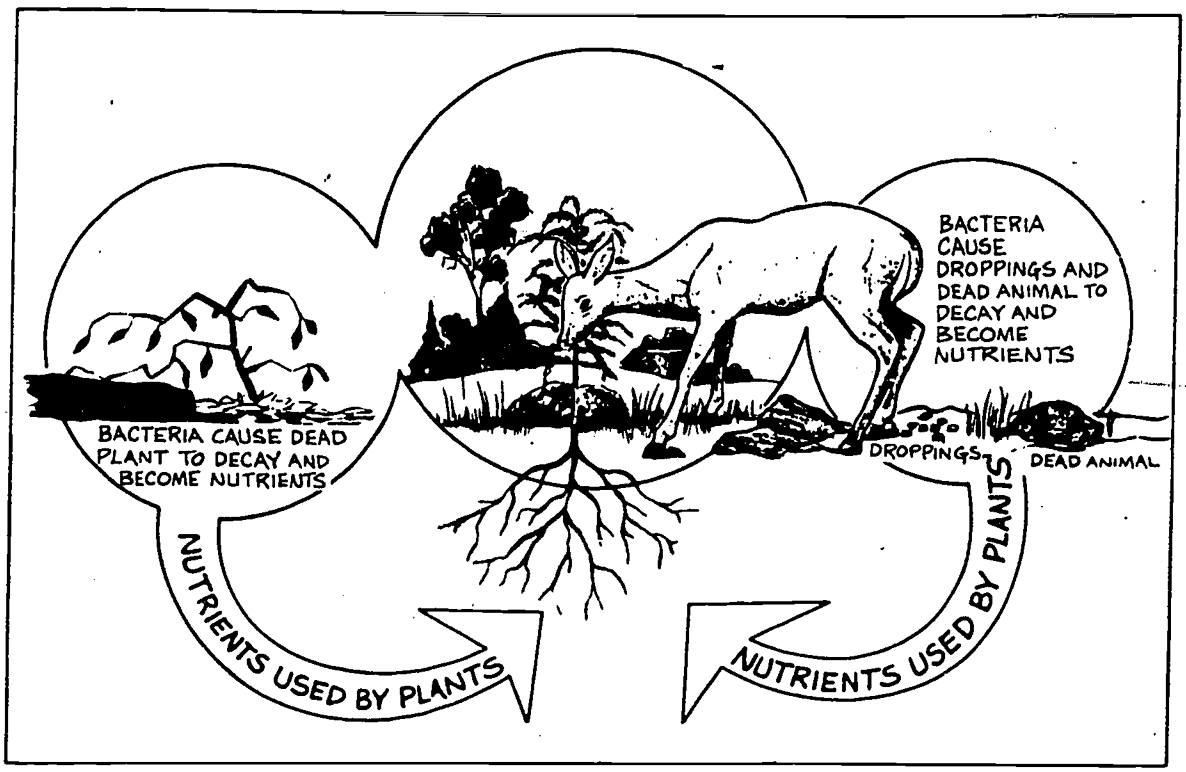
In general, carbon can be found in lots of different forms as it is moved or cycled through the ecosystem. Some of the places where carbon is found are shown in the picture below. This picture shows how carbon is cycled through the ecosystem.

The carbon cycle.



All of the materials in the ecosystem are recycled. Some are particularly important in ecological relationships. One of these is nitrogen.

Like carbon, nitrogen is a basic ingredient for life. A good place to start in the nitrogen cycle is when it is a gas in the air. When it rains, nitrogen sometimes combines in a chemical way with the water and falls to the soil. Here, certain kinds of bacteria called nitrogen-fixing bacteria make the nitrogen into a chemical compound that plants need. These bacteria live in the soil near the roots of plants like clover. After the nitrogen-fixing bacteria change the form of nitrogen, plants gather up nitrogen and use it to make new stems, roots, and leaves. Animals eat the plants and perhaps other animals eat these first animals. When the animal dies, the nitrogen is given off into the air from the decomposing flesh. So, it is back into the air as a gas. More parts can be added to the nitrogen cycle. Some of these are shown in the picture below.



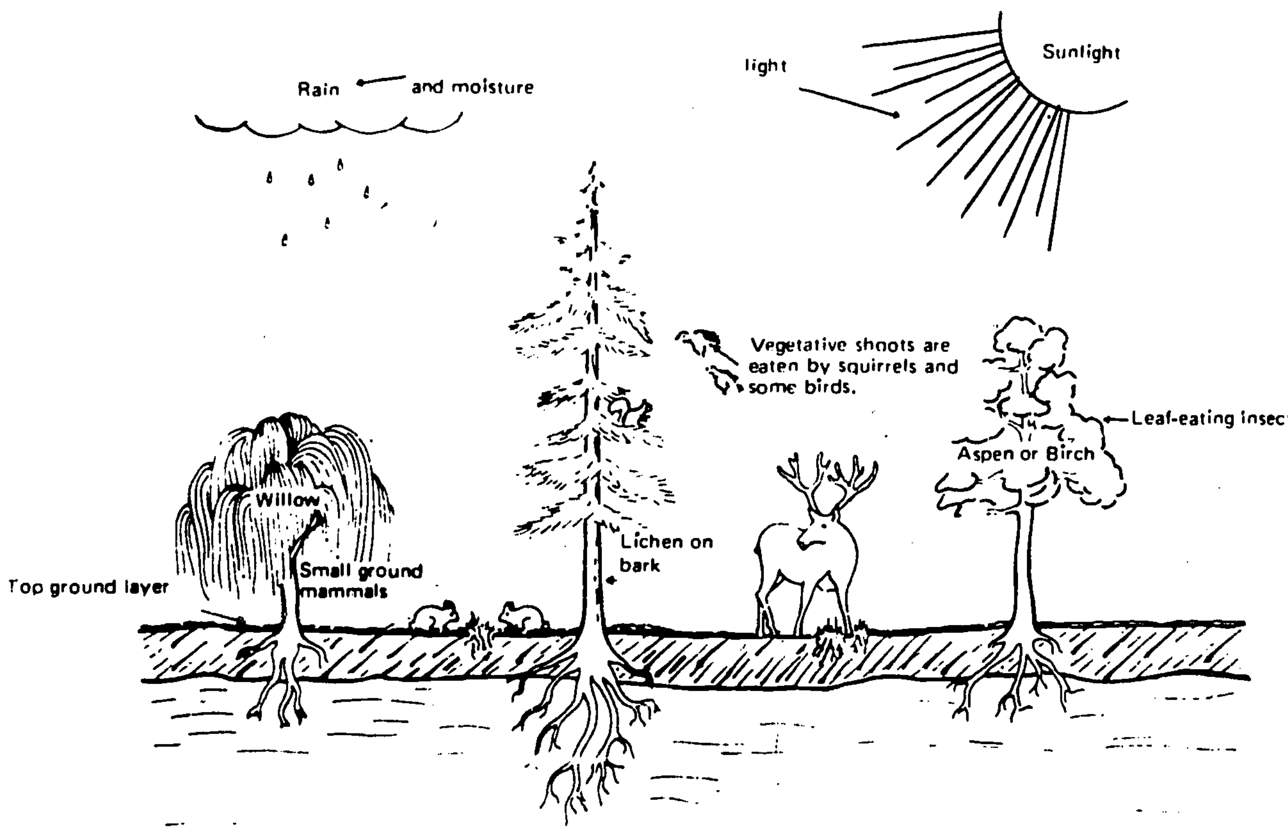
Actors in the Cycles of Materials

We have seen that there are several parts to the cycles of materials in the ecosystem. Each one of the living things that has a part in these cycles can be grouped into a category. For example, plants make organic materials made up of nitrogen, carbon, and other things which other living things use. We call plants producers. Other living things, especially animals, eat the plants to get energy and recycled materials. This group is called consumers -- they consume the organic materials produced by the plants. A third group of actors in the cycle of materials is the group of living things which get the materials out of organic materials and put them back into the soil or the atmosphere. These living things are called decomposers. They help break down, or decompose, complex organic materials, like bone or leaves, into simple organic materials like nitrogen and carbon. Snails, maggots, fungi, and bacteria are good examples of decomposers.

When we want to speak about the way materials like carbon are recycled in general, we can use the names of these three groups of living things -- producers, consumers, and decomposers. For example, carbon usually is cycled from the environment to producers to consumers to decomposers and back to the environment. But this is only true for most of the time. An important exception would be when a plant dies, its carbon might never get to a consumer. It might go right back into the air as carbon dioxide to be used by another plant. This is still a cycle for carbon, only it's a shorter cycle than we usually find in the ecosystem.

MATTER AND ENERGY: PUTTING IT ALL TOGETHER

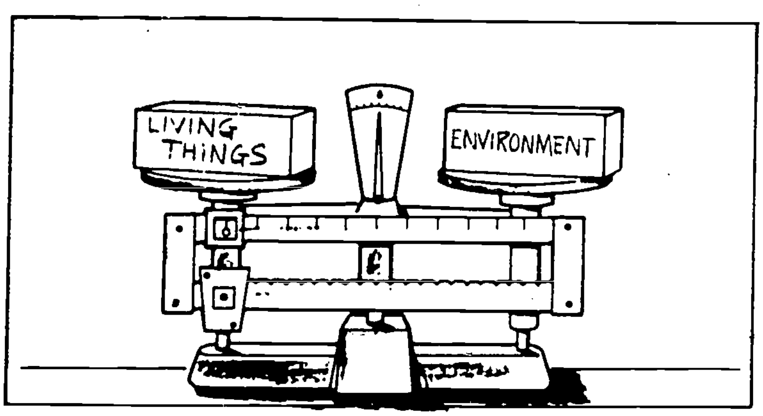
The foothills is a natural system -- all of the living things are affected in some way by other living things or by non-living things like the amount of rainfall. For example, look at a simple version of the ecosystem in the picture below. Every one of the living things pictured there depends on all of the other things in the picture. The tree needs water from the atmosphere. It also depends on decomposers to break down dead leaves, animal wastes, and dead animal tissues into basic ingredients for life -- oxygen, nitrogen, calcium, and so on. The trees also provide a nesting place for birds. The birds, in turn, help the trees by eating insects that are harmful to the trees.



Trees provide food for other animals -- bark and new buds for deer; seeds like acorns and walnuts for squirrels and grossbeaks. Without trees to provide food for squirrels, there would be few squirrels for predators like hawks and foxes to eat. This would mean that these predators would turn to other sources of food like rabbits and snakes. So the trees also have an effect on rabbits and snakes too.

What would happen if some of the things in this simple version of the ecosystem were taken away? For example, suppose humans killed all the rabbits to make fur coats and fur-lined gloves. Immediately, the amount of clover that used to be eaten by the rabbits would start to increase. Clover would edge out some other kinds of grasses and plants that are food for gophers. Without rabbits and with fewer gophers, hawks and foxes would have to concentrate on other animals for food. Snakes and field mice might be hunted by these predators more than before. The insects that these animals eat would now be able to grow with less chance of being eaten. This increase in insects might result in a decrease of the grain crop for humans.

We could go on and on. You can see that nature has created a delicate balance in ecosystems. Changing even one little part of that balance can have large effects on the whole system. But nature also has ways of bringing back or restoring the balance. These ways ususally take a long time, however.

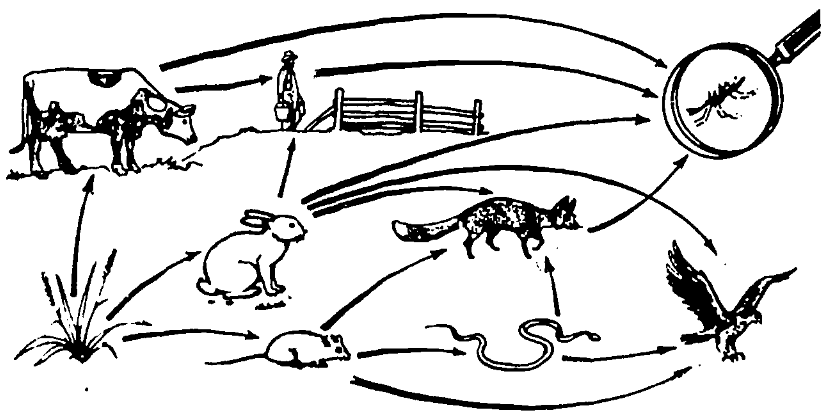


Resources

You can name some important resources for humans -- coal, oil, and metals like iron and tin. But have you ever stopped to think that rabbits are a valuable resource? How about snails? Or water? Humans are usually concerned with things that affect their lives only directly. If we use up all the natural supplies of coal and oil, we'll have a serious problem for heating our homes. But things that affect the whole ecosystem also have an effect on resources that are less obvious but just as important. For example, if we pollute the streams with sewage, it will take longer for substances like carbon and nitrogen to get back into their natural cycles. Without snails to help decompose dead plant materials, we have to wait longer for other decomposers to work for us. And without enough of these important substances like carbon, we won't have enough grain or vegetables. Our resources are all around us. Each and every living thing is a resource that we should use wisely. Otherwise, our ecosystems will change, perhaps in ways that are harmful to us.

Food Chains and Food Webs

Much of what we've been talking about has to do with how energy and materials move through the ecosystem. Before, we looked at the relationships between rabbits and gophers as prey for hawks and foxes. A simple predator-prey relationship like the one between a hawk and a rabbit is an example of one link in a food chain. We can think of other links, too. The rabbit eats clover. Decomposers live off the decaying flesh of dead hawks. When we put all this together, we have a food chain -- clover to rabbits to hawks to decomposers. Both materials and energy are passed along this food chain.



But we also know that more than one animal eats rabbits to get organic materials and energy. For example, hawks eat rabbits and so do snakes. Hawks also eat snakes. We are beginning to make the simple food chain have a lot of complex relationships. We call all of these relationships together a food web. The food web is a way of showing how lots of living things are all related to each other for moving materials and energy through the ecosystem.

POPULATIONS

Imagine yourself walking through the foothills. As you walk through the forest of foothill oaks, you come upon an open meadow of grass. Then, sitting down quietly, you see a group of ground squirrels busy collecting food. These ground squirrels have built underground homes and are storing acorns and berries in them for the winter ahead.

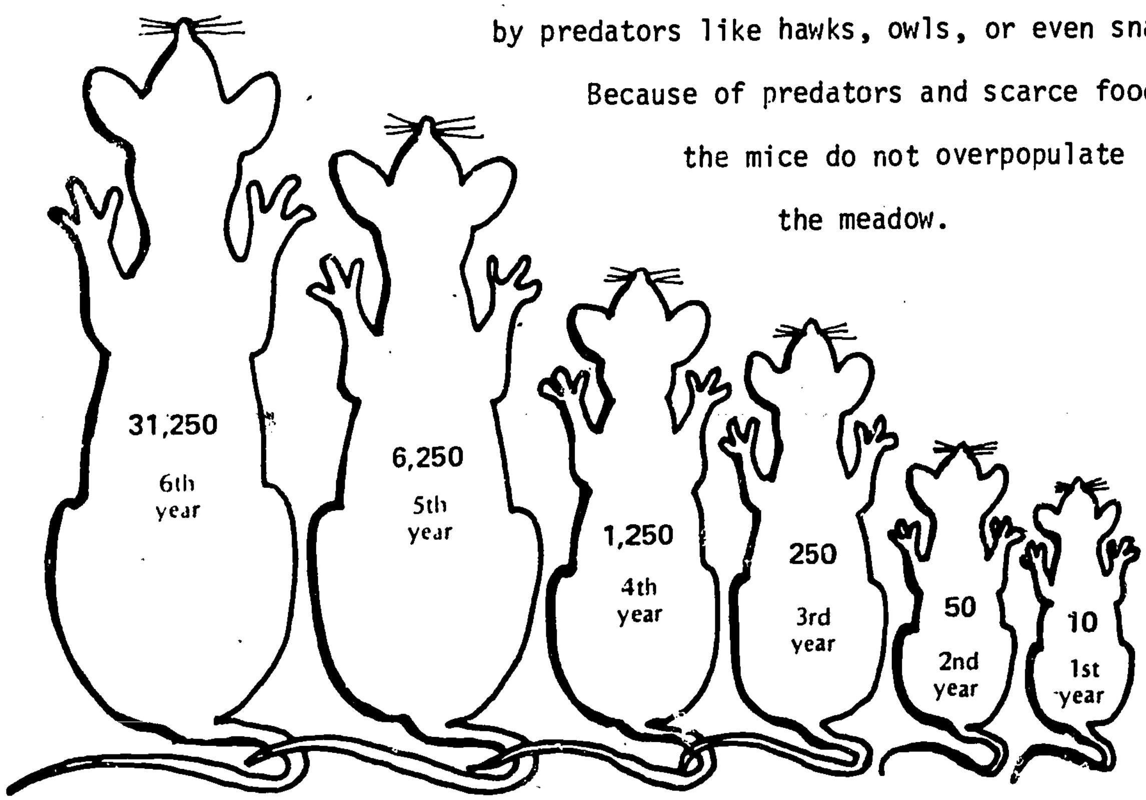
Nearby, in the shrubs, there is a flock of field sparrows collecting seeds from weeds and blueberries. The sparrows all move together in a flock as they fly to a new group of shrubs.

We have been observing the populations in the foothills ecosystem. The ground squirrels, sparrows, and blueberry bushes are each examples of populations. Another population we didn't mention was the group of black ants who are gathering tiny pieces of food left by a ground squirrel after finishing his lunch of acorns.

A population is a group of one kind of living thing or organism. For example, the group of black ants was one population. A group of red ants is a different population. Populations are not only groups of similar animals, but they also can be groups of similar plants or even of similar microorganisms like bacteria. These populations are similar kinds of animals or plants and they live in the same geographic area.

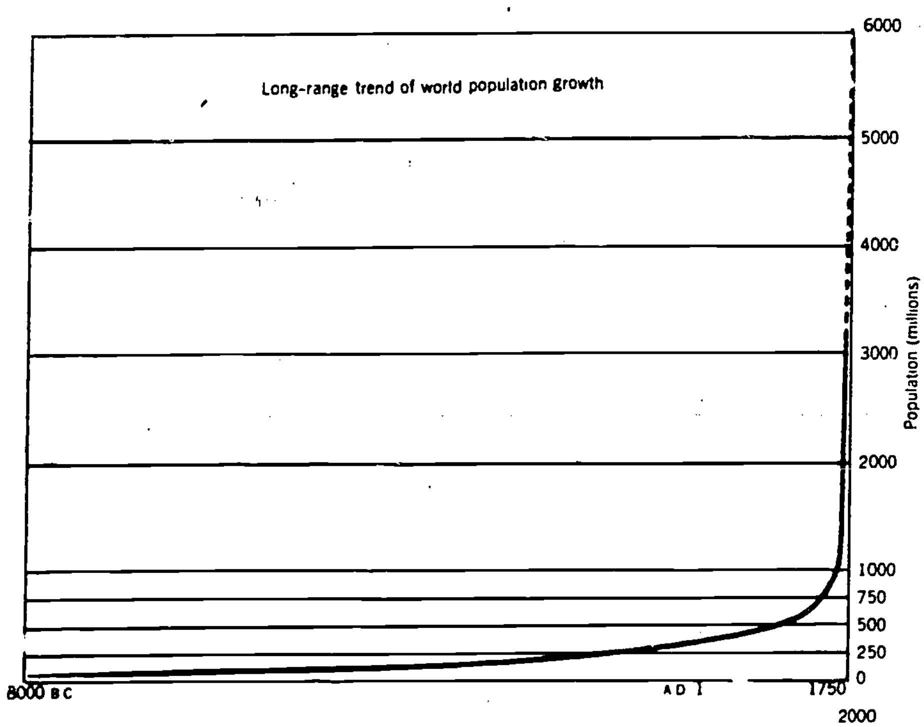
When ecologists study populations, they are usually interested in what causes the population to become bigger or smaller. There are two causes for population increases, 1) birth, and 2) immigration. If we started out with a group of 10 field mice (5 males and 5 females) and allowed them to reproduce, we could make a graph of the number of mice there would be in future years. In order to make this graph we need to know the birth rate of the mice and the rate at which they die. Let's say that each pair of mice can have 10 babies every year, and that each mouse only lives for one year. At the end of the second year there would be 50 mice -- the 5 sets of 10 babies each. (Remember, the original 10 mice are now dead because they only live one year.) At the end of the third year there would be 250 mice. After 4 years there would be 1,250 mice, and at the end of 6 years there would be 31,250 mice! Imagine what would happen if there was no way to control the size of the mouse population. We would be up to our ears in mice in no time.

What controls the size of the mouse population? First of all, not all young mice babies grow up to be adults. Some mice babies die because of lack of food, others die because they are eaten by predators like hawks, owls, or even snakes. Because of predators and scarce food, the mice do not overpopulate the meadow.



There is a balance between the reproductive rate of mice and their death rate. This balance keeps the size of the mouse population about the same from year to year.

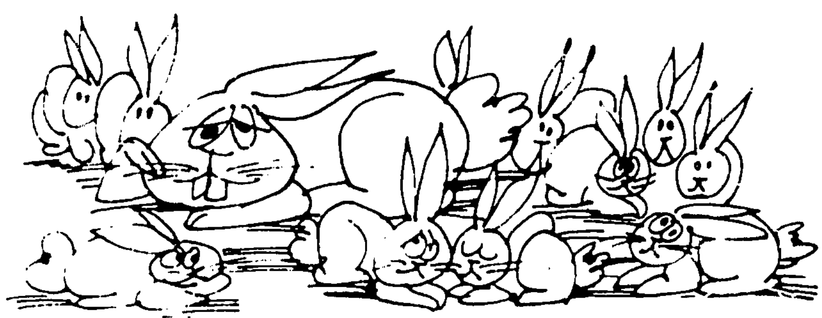
Does this same idea of balance also describe human populations? Yes, but there are some differences. Humans are able to think and discover things about themselves and the environment they live in. One of the things that humans have developed is medicine. With improved medical knowledge, the number of humans that die during childhood is getting less and less. This increases the size of the population. Medicine has also helped humans to have a longer life span by reducing the number of deaths due to diseases. Another difference between other organisms and humans is that humans do not have any predators -- there is nothing that feeds on humans and decreases the size of their population.



A long-range view of world population growth from 8000 B.C. to 2000 A.D.

There is at least one control on the size of human populations. That is lack of food. As the human population of the world gets larger and larger, the amount of food available for each person gets smaller and smaller. The preceding graph shows how the human population has grown in the last 10,000 years.

This increase has alarmed many ecologists. They say that the human population growth must be controlled or we will overpopulate the whole world and starve. Birth control is one method for limiting the size of the population. Can you think of other things that will help humans solve this problem?



COMMUNITIES

If you were alone in Foothills Park, what would you be likely to see all around you? Would you see a rhino crashing through giant ferns? Would you see a kangaroo fighting with a giraffe over who was going to eat an ostrich egg? Would you see a python sliding down a palm tree after a penguin? You probably know that none of these animals and plants are in the foothill ecosystem. Most of them would never be neighbors of each other anywhere else. We know they do not share the same habitat or living area.

Well then, why do certain animals live in the foothills and others do not? Part of the answer is in the idea of a community. Some animals, like squirrels, live near trees because food is available and they can nest safely in the tall trees. They are not perfectly safe, as the grey fox well knows. He is attracted to the area because lots of squirrels mean easy food for him. He also prefers a habitat where there is low ground cover in addition to the trees. This adds variety to his menu in the form of mice, berries, and a quail or two. Humans moving into the area start farms and keep chickens, which is convenient from a fox's point of view. But part of what attracts the fox, namely the berries, also attracts birds to the area. Berries are good food for birds; besides, lots of bushes mean lots of tasty insect meals for the birds. Other neighbor animals, plants, or insects that are parts of food chains live near each other.

Most animals live where they do because the community of living things provides what they need. This means that the different populations depend on each other. The dependence of several different populations all living in the same general area is what we mean by an ecological community.

Let's go back to some of the absurd things mentioned at the beginning of the lesson. Why wouldn't you see a kangaroo fighting with a giraffe over an ostrich egg? First of all, the kangaroo is not found in the same area as the giraffe -- kangaroos live in Australia while giraffes live in Africa. But even if they were in the same place, they wouldn't be likely to live in the same community. Kangaroos eat grasses and low leafy shrubs. Giraffes eat leaves from moderately tall trees. Usually, the kinds of plants kangaroos eat wouldn't grow in the same area as the trees that giraffes feed on. So, they wouldn't be likely to be found near each other since each animal would need to live near its source of food. And the fact that both are vegetarians rules out the possibility of them fighting over an ostrich egg.

In terms of the way different populations depend on each other and live near each other in a community, it would be very rare to even find a giraffe and a kangaroo together. They have little in common and neither one depends on the other one for anything. So we see that an ecological community is built around the needs of living things and the satisfaction of those needs by other living things.

Let's go back now to the community of the foothills. If all the different animal and plant populations depend on each other in a community, what happens to the community if something happens to one of the populations? For example, what might change if a disease swept through the low plants and grasses killing off a large part of the food web? Or suppose there was a forest fire?

Major changes in the community like a disease or a fire have large effects. In fact, they often mean that the whole community changes. Think about the forest fire. It would burn away lots of plants that were food for insects, rodents, and birds. These populations would have to move to new areas and make new communities. But with all of the big trees gone, there would be lots of room for little seedlings to grow. These would attract deer since seedlings are a favorite food for deer. But the deer wouldn't eat all of the seedlings and shrubs trying to grow back. Soon, there would be lots of small bushes and grasses. In place of the squirrels who used to live in the tall trees, field mice and gophers would start to burrow in the ground. Snakes that fed on these kinds of animals might move into this developing community. After several years, a whole new and stable community would be in place to take the spot where once there was a forest community.

The several different kinds of communities -- like the forest community that burned away and the grassland community that replaced it -- all are based on the way different plant and animal populations adapt to and depend on other populations in the same area.

ECOSYSTEMS

A community is a group of populations that live in the same area and depend on each other. This is usually because they are all connected by <u>food chains</u> or <u>food webs</u>. The foothills community consists of oak trees, foxes, owls, hawks, ants, fish, and many other animals and plants. A community exists in the non-living world, too. Thus, it is necessary to think about things like the climate, the water cycle, and other non-living things to get a complete picture of life in our world. When we talk about the community of living organisms and the non-living environment together, we are talking about an <u>ecosystem</u>.

What are some of the parts of the non-living environment that affect how quickly communities grow and how well they survive? Ecologists have studied this question and have found some answers. The most important factor in the non-living environment is <u>climate</u>. Climate has two basic parts: temperature and moisture.

The temperature of the climate is determined by several factors. One is the distance from the equator. Ecosystems that are closer to the North or the South Poles are colder. Those nearer the equator, like southern Mexico, are warmer. Altitude is another important factor that helps determine the temperature. The higher you go above sea level the colder it gets. This is because air helps hold the warmth the earth gets from the sun. The air gets thinner as we go up in altitude, so it gets colder. There is a place right on the equator that has snow all year round -- it's in Africa on top of Mt. Kenya. Another influence on the temperature of an ecosystem is its distance from a large body of water.

Ecosystems that are close to the oceans generally have little temperature variation from season to season. This is because water is slower to change temperatures than land. Along the California coast the temperature might vary from 30°F in the winter to 80°F in the summer. But in Iowa, where there is no ocean, the temperature varies from -20°F in winter to 110°F in the summer.

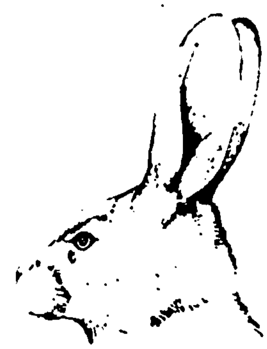
Moisture is another important aspect of the climate. The moisture of an ecosystem is affected by how far it is from the oceans. The closer the ecosystem is to oceans, the more moisture. The presence of mountains affects the moisture of an ecosystem, too. Clouds that carry moisture in the form of water vapor cannot get over the mountains easily, so the side of the mountain which the cloud passes over first will be moist. The other side will be drier because the clouds have lost most of their moisture. An example of this is the difference between the moisture in the San Joaquin Valley on the west side of the Sierra Mountains and the Great Basin of Nevada which is on the east side.

Another factor affecting ecosystems is the types of soil. Some soils are full of rocks, some are sandy, some have a lot of clay and others are very rich in organic materials. Not only do soils differ in what they are made of, but they also differ in the amount of water they can hold. A clay soil does not hold much water but one that is full of organic matter does. The more water, the easier it is for plants and other living things to live there.

Soils also differ in the amount of nutrients they have in them, and how fast they can replenish their supply of nutrients. Soils that are near the equator generally have lots of nutrients. Their supply is quickly replenished because there are lots of plants and animals to add nutrients back into the soil. Soils in the tundra regions like northern Canada and Alaska have fewer plants. It takes a long time for nutrients to be replenished once they are depleted.

So far we have been talking about the factors which make up the non-living environment. But how do these things affect the living things and the ecosystem as a whole? We don't find cactus in the redwood forests of northern California. Neither do we find redwood trees in the desert. This is because each of these plants is adapted to a particular habitat. Through the processes of evolution and competition, plants and animals have adapted themselves to live in their living and non-living environment.


Jack rabbit (desert)


Rabbit (forest)


Arctic hare (Arctic)

Let's look briefly at an example of how evolution helped rabbits to adapt to their climates. Rabbits are warm-blooded animals. This means they need to keep their body temperature about the same all the time -- just like humans keep their body temperatures at about 98.6°F. Rabbits have evolved so that their ears help them do this.

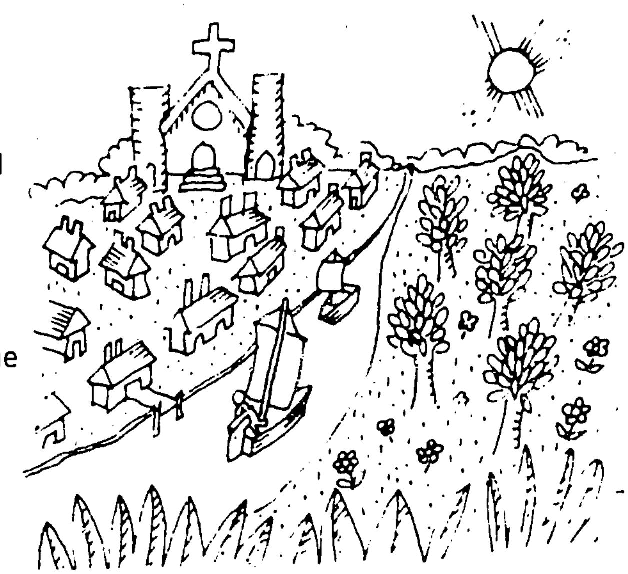
Snowshoe rabbits that live high in the mountains where it's cold have small ears. The less body area that is exposed to the cold, the more heat they can keep to maintain their body temperature. On the other hand, rabbits that live in the hot desert have very large ears. These larger ears help to cool the rabbit as he runs or flicks them about by allowing air to rush by the ears and cool the blood that circulates through them. The blood then circulates to help cool the rest of the rabbit's body. As you might guess, rabbits that live in places where temperatures are medium have medium-sized ears.

There is an interplay between the living world and the non-living world which makes up an ecosystem. If there are changes in the non-living world there will also be changes in the living world. It is these relationships that ecologists are concerned with. The complexity of all this is what makes ecology so interesting.

PEACEFUL LAKE: THE IMPORTANCE OF ECOLOGY*

A la e community of plants and animals lives in and around Peaceful Lake. Sunlight falls freely on the plants on land and in the water. Animals and humans drink freely from the stream that flows away from the lake and from the lake itself. Many varieties of fish live in the lake and its feeder and outlet streams -- bass, trout, perch. Birds live easily eating the insects that thrive on the dense foliage. Hawks have a wide menu of field mice and fish. Frogs, snails, crayfish, turtles, beaver, deer, fox, and many other kinds of living things, both plant and animal, make their homes in or near Peaceful Lake. Indians gather berries and nuts, and hunt the abundant animals only for food.

European fur trappers were the first whites to discover Peaceful Lake. They trapped many beaver for fur and carried news of the beautiful land to settlers itching for new homes in the rich territories. Soon, a small village grew around the lake.



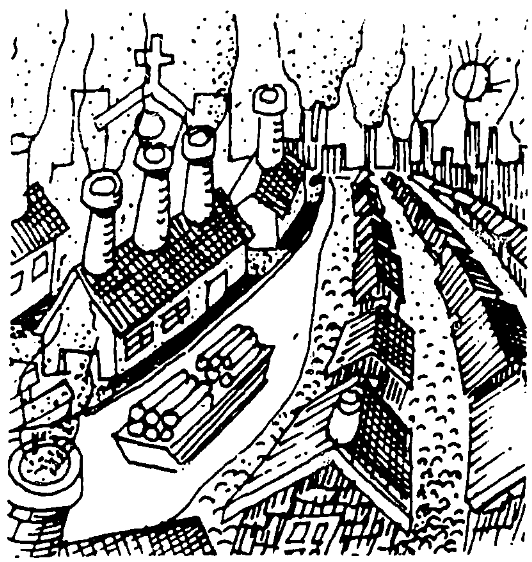
The land was fertile and moist. Crops grown there could provide food for many families. Moose and deer from the forest, fish from the lake, and ducks and geese added meat to the settlers' diet. There was much fur trading because of the many mink, beaver, and fox living nearby.

All in all, life was ideal at Peaceful Lake in the 1700s.

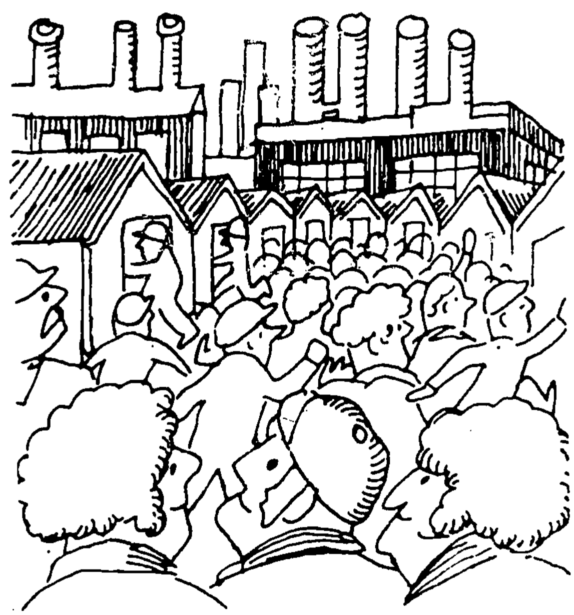
*Adapted from "Changes at Peaceful Lake" in Science Curriculum Improvement Study, Ecosystems, Teacher's Guide (Chicago: Rand McNally, 1971). Copyright © 1971 by The Regents of the University of California, Berkeley, California. Permission granted by the publisher.

As the word about Peaceful Lake spread, more and more people were attracted to the area. Soon the lakeside human population was too large to be supported by the existing fields. Forests were cleared to develop more and more farmland. With less forests, the animals that had provided the settlers' meat also disappeared. Farmers began to raise cattle and sheep for meat, and more forests were cleared to provide grazing land for these animals.

When the forests were cut down, fur-bearing animals disappeared. The settlers no longer had furs to trade for items like cloth, weapons, and plows. They began to make these things themselves, and soon their workshops grew into factories. The factories produced not only things they used themselves, but also other items for trade.



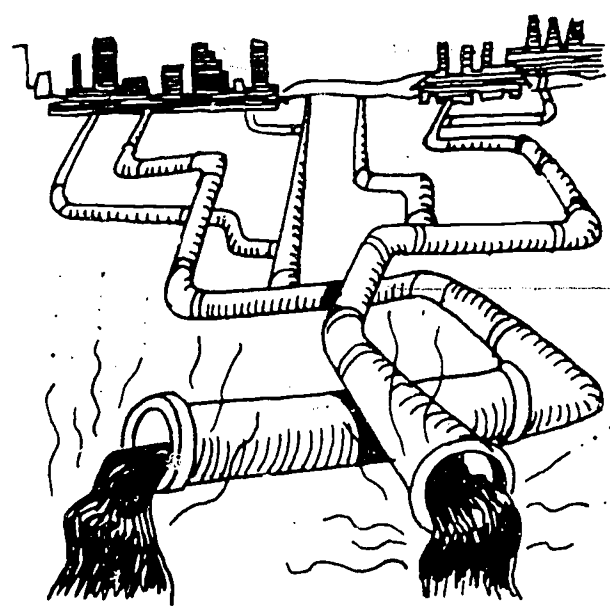
Many factories were successful, and people were attracted from other areas to work in them. As a result, population increased, additional food was required, and the remaining forests were converted into cropland. Slowly but surely, the lake area changed into the huge industrial and agricultural center.

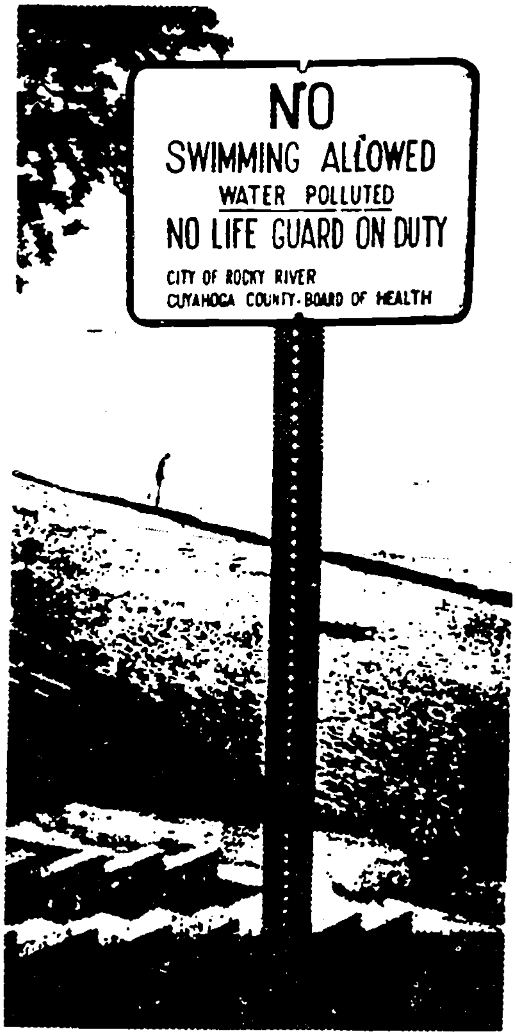


Soon after lakeshore industry was firmly established, there were no more forests that could be cleared for farming. In order to produce enough food to feed the rapidly growing population, the lakeside farmers stopped rotating crops and planted food crops on all available land. Within a few years they discovered they had made a mistake, for their yields decreased until finally some farms could produce no crops at all.

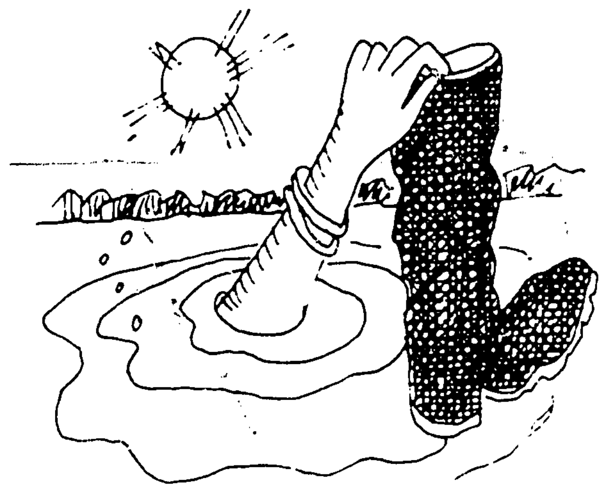
About that time, fertilizers were developed. This allowed farmers to plant all their fields every year, without worrying about using uo the minerals in the soil because these were supplied by fertilizers.

When a group of people lives in one area, there is a huge amount of waste material produced. Tons of garbage and sewage must be disposed of each day. Because it was an easy way to deal with the problem, waste disposal lines from factories and sewage lines from homes were run to the water's edge. Garbage was dumped from piers. Before long, people stopped dumping garbage into the lake because much of it floated and was ugly. The sewage was not visible, however, so there seemed no harm in continuing to dump it into the lake.

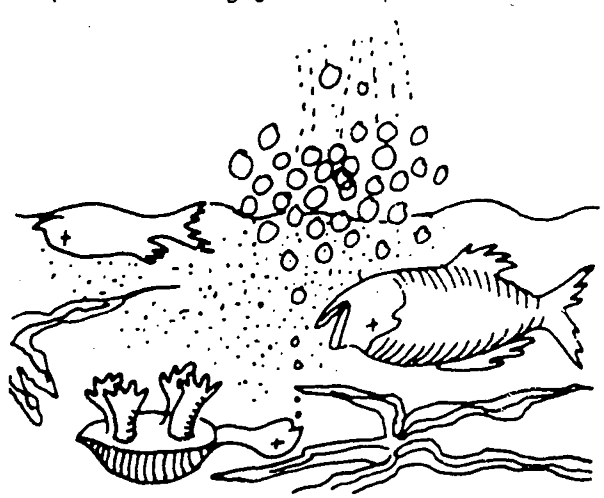




A few years ago, people noticed more algae in the lake than before. At first, only a few small clumps that had been washed ashore, or a green film on offshore rocks, was visible. Then swimmers complained about the slime that clung to their bodies



when they came out of the water. And boaters described large, propeller-snagging masses of algae floating on the surface of the lake. Soon, the mayor's office was swamped with angry descriptions of the foul odor found everywhere near the water. By this time, no more fishermen lived near the lake. They had moved elsewhere in order to catch enough fish to support their families. Recently, a reporter on the local newspaper wrote that the crowds of Sunday afternoon swimmers and picnickers on the beaches had been replaced by dead fish and masses of rotting algae.



APPENDIX B

OF

A FACTORIALLY DESIGNED EXPERIMENT ON

TEACHER STRUCTURING, SOLICITING, AND REACTING

November 1976

MASTER LESSON PLANS FOR LESSONS 1-9 FROM WHICH THE EIGHT TREATMENT VARIATIONS MAY BE RECONSTRUCTED

Program on Teaching Effectiveness

Stanford Center for Research and Development in Teaching

MASTER LESSON PLANS

This appendix consists of the master lesson plans for a nine-lesson unit on ecology. The master lesson plans are the source from which the eight versions of the recitation strategy were constructed.

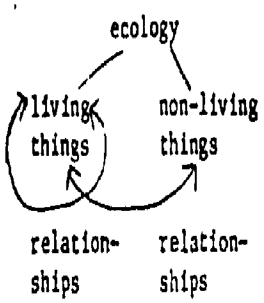
Each page of a master lesson plan is divided into six columns:

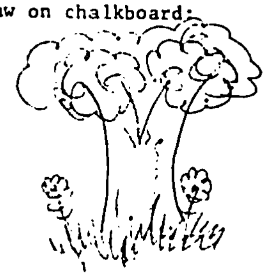
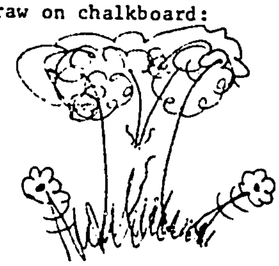
St+	High Structuring
St-	Low Structuring
So+	High Soliciting
So-	Low Soliciting
Re+	High Reacting
Re-	Low Reacting

The lesson plans for each of the eight versions of the recitation strategy were composed by cutting the appropriate three columns from each page of the master lesson plan, assembling these columns, and photocopying them. For example, the lesson plans for the High Structuring, Low Soliciting, High Reacting treatment consisted of the material in the St+, So-, Re+ columns from each master lesson plan.

During the course of the experiment, the teachers referred to the lesson plans as a lecturer might in delivering a lecture. This procedure ensured that the content presented for a given lesson by each teacher would be nearly identical and that the treatment variations would be delivered as similarly as possible by the four teachers. Each teacher was trained specifically on each of the lessons and on each treatment variation. Consequently, the teachers could use the lesson plans primarily for quick reference rather than having to read or refer to them at length.

St+	St-	Sc+	Sc-	Re+	Re-
In the next 2 weeks, we'll be learning about ecology. You've already read about some of the basic aspects of ecology. The objectives for today's lesson are: 1. to learn about 5 basic relationships between living things. 2. to briefly explore what an ecosystem is, 3. to introduce ecology as a science.					
Let's begin today's lesson by outlining what we'll be looking at. Some of these are things you have read about and others will be discussed in class.					
Ecology: 1. definition - the study of relationships between living things and other living things and between living things and non-living things on earth.					

St+	St-	Sc+	Sc-	Re+	Re-
2. diagram on chalkboard: a.  b. there are five basic relationships: (1) predator-prey (2) benefit-no difference (3) mutual benefit (4) - } I'll talk (5) - } about these later.					
3. Ecosystem is a basic idea in ecology; we'll look at a. characteristics of an ecosystem b. what it means to say it's a <u>system</u> 4. We'll see how ecology is a science.					

St+	St-	Sc+
Let's get into the lesson through an example of a "miniature" ecosystem		
	Today we're going to begin to learn about the science of ecology.	
Draw on chalkboard:  oak tree - leaves, acorns, bark, lichen (algae, fungus) birds - robin, sparrow, woodpecker, wren, bluebird mammals - squirrel, chipmunk, gopher insects - caterpillar, grubs (in bark), moth, bee other plants - flowers, climbing vines, grass	Draw on chalkboard:  oak tree - leaves, acorns, bark, lichen (algae, fungus) birds - robin, sparrow, woodpecker, wren, bluebird, bluejay mammals - squirrel, chipmunk, gopher insects - caterpillar, grubs (in bark), moth, bee other plants - flowers, climbing vines, grass	

St+	St-	Sr+	Sr-	R+	R-
There are many ecological relationships around this oak tree. Some of them are other examples of ones you read about before.	There are many ecological relationships around this oak tree.				
		(hi) What's one example of an ecological relationship between living things here? predator-prey: robin - caterpillar, moth woodpecker - grub bluejay - caterpillar, moth benefit - no difference: squirrel nest - tree moth - (using) tree (as camouflage) bird's nests - tree climbing vine - tree mutual benefit: bee - flowers squirrel - tree (spreads seeds) lichen - algae provide sap for fungus which collects water in cuplike structure	(lo) Since the robins eat the caterpillars, what kind of relationship is this? predator - prey	praise "no" + reason prompt on board	neutral "no" probe
			(lo) Since woodpeckers eat grubs what kind of relationship is this? predator - prey	praise "no" + reason prompt on board	neutral "no" probe
			(lo) Birds nest in the trees which does no harm to the tree but helps the bird. What kind of relationship is this? benefit - no difference	praise "no" + reason prompt on board	neutral "no" probe
			(lo) The vine climbs up the tree to get closer to sunlight. What kind of relationship is this? benefit - no difference	praise "no" + reason prompt on board	neutral "no" probe
			(lo) What kind of relationship is there between the bee and the flowers? mutual benefit	praise "no" + reason prompt on board	neutral "no" probe

242

298

297

St+	St-	Sc+	Sc-	Re+	Re-
		Competitive: squirrel, chipmunk - acorns robin, bluejay - caterpillar or moth moth, caterpillar - tree leaves wren, bluebird - wood-pecker holes for nests Combined: robin - moth, moth - tree, robin - tree squirrel - tree, squirrel vs. chipmunk - tree, tree (as nest) - squirrel ...Obtain two examples of each of the 3 types of relationships in the reading (predator - prey, benefit - no difference, mutual benefit)	The lichen consist of (lo) 2 parts - one where the fungi, who can't make food, lives off the sap from the algae while the algae, which has no roots to draw water, lives in the cuplike fungi where water collects. Since both living things gain at no loss to the other, what kind of relationship is this? mutual benefit	praise "no" + reason prompt on board	neutral "no" probe
Although things like the squirrel eating acorns or the caterpillar eating leaves of the tree seem like predator-prey relationships, they are not. Prey can be only animals - birds insects, reptiles like snakes, and so on. Animals eating plants or plant materials like acorns is NOT a predator-prey relationship. It's just called eating.	Although things like the squirrel eating acorns or the caterpillar eating leaves of the tree seem like predator-prey relationships, they are not. Prey can be only animals - birds, insects, reptiles like snakes, and so on. Animals eating plants or plant materials like acorns is not a predator-prey relationship. It is just called eating.				

243

St+	St-	Sc+	Sc-	Rc+	Rc-
Let me summarize the 3 relationships you read about and we discussed. (1) predator-prey, like... (2) benefit - no difference, like... (3) mutual benefit, like...					
		(h) What do these three relationships have in common besides the fact they involve only living things? 1. 2 parts 2. one part has an effect on the other	(lo) How many living things take part in the predator-prey relationship in this ecosystem? 2 parts	praise "no" + reason prompt on board	neutral "no" probe
			(lo) Since one part of a relationship, say a robin does something to the second part the caterpillar, a relationship also involves one thing doing what to another? affecting - causing an effect	praise "no" + reason prompt on board	neutral "no" probe
Right - as relationship always involves 2 parts, one which has an effect on the other, put on chalkboard: 2 parts 1 affects the other					

244

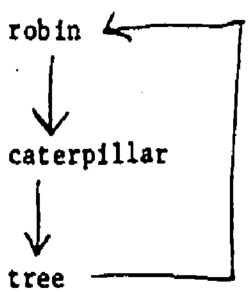
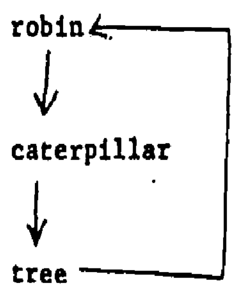
St+	St-	Sc+	Sc-	Rc+	Re-
Remember I said we'd look at 2 other important relationships? Let's turn to these now.					
		Can you think of a relationship between the squirrel and the chipmunk? (hi) both eat acorns	What does a squirrel eat? (lo) acorns What does a chipmunk eat? (lo) acorns	praise "no" + reason prompt	neutral "no" probe
If there weren't enough acorns for both the squirrel and the chipmunk, then one would begin to starve because the other was eating enough food. This type of relation is called a competitive relationship. on board: competitive The two animals compete for the same source of food. This is a very important kind of relationship in ecology, and we'll study it often in later lessons.	If there weren't enough acorns for both the squirrel and the chipmunk, then one would begin to starve because the other was eating enough food. This type of relation is called a competitive relationship. Both animals compete for the same food.				

245

St+	St-	Sc+	Sc-	Rc+	Rc-
		(hi) Can you think of another example of a competitive relationship for our oak tree ecosystem? 1. robin, bluejay - moth 2. moth, caterpillar - plant leaves 3. wren, bluebird - abandoned woodpecker holes ...obtain at least 2 of the above	(lo) Since the robin and the bluejay both eat moths, what kind of relationship is this? competitive	praise "no" + reason prompt on board	neutral "no" probe
			(lo) How about the wren and the bluebird who both like to use abandoned woodpecker holes for their nests - what kind of relationship is this? competitive	praise "no" + reason prompt on board	neutral "no" probe
So far, most of the competitive relationships have involved competition for food. There are other reasons. 1. wrens, bluebirds compete for nesting sites 2. gophers, chipmunks compete for territory on the ground 3. all the animals might compete for water during a drought It's important to realize that competitive relationships are not limited to competing for food.	So far, most of the competitive relationships have involved competition for food. There are other reasons. 1. wrens, bluebirds compete for nesting sites 2. gophers, chipmunks compete for territory on the ground 3. all the animals might compete for water during a drought				

St+	St-	Sc+	Sc-	Rc+	Rc-
		(hi) Is a competitive relationship really a relationship like the types of relationships we talked about before? yes	(lo) Looking at the competitive relationship between, say, the gophers and the chipmunks who compete for territory, does this relationship have at least 2 parts? yes	praise "no" + reason prompt	neutral "no" probe
		(hi) How does a competitive relationship fit the definition of a relationship? 1. it has at least 2 parts, say the gopher and the chipmunk (or any other will do) 2. one part has an effect on the other; if the gopher gets the territory, the chipmunk doesn't	(lo) And since the chipmunk gets the territory if the gopher doesn't, does one of the parts have an effect on the other? yes	praise "no" + reason prompt	neutral "no" probe
So we see that the competitive relationship fits our general description of an ecological relationship by involving at least two parts, one of which has an effect on the other. on board: competitive relationship= 1. 2 parts 2. one affects the other					

247

St+	St-	Sc+	Sc-
I said before we'd look at <u>2</u> new relationships. We've already discussed one - the competitive relationship - and how it fits our description of relationships in general. And, we've seen that competition can be applied to more than just food - like nesting and territorial competition.			
The next kind of relationship can be pictured this way: on board: 	The fifth kind of relationship can be pictured this way: on board: 		

St+	St-	Sc+	Sc-	Re+	Re-
		(1o) Can you name each of the relationships in this diagram? 1. predator - prey (robin - caterpillar) 2. eating (caterpillar-tree) 3. benefit - no difference (robin nests in tree)	(1o) Can you name each of the relationships in this diagram? 1. predator - prey (robin - caterpillar) 2. eating (caterpillar - tree) 3. benefit - no difference (robin nests in tree)	praise "no" + reason prompt on board next to appropriate arrows	neutral "no" probe
When there is more than one relationship chained together like this, we call it a combined relationship. on board by diagram: combined relationship These relationships are very important in the ecosystem - we'll see why in a few minutes.	When there is more than one relationship that is related like this, we call it a combined relationship.				
Let's look at some combined relationships for a few moments.					

249

St+	St-	Sc+	Sc-	Rc+	Rc-
	Give a second example of a combined relationship	(hi) Can you see any other combined relationships in our oak tree ecosystem? example: 1. squirrel vs. chipmunk moves acorns around spreading seeds - mutual benefit competitive tree 2. robin $\xrightarrow[\text{prey}]{\text{predator}}$ moth nesting benefit- no difference moth eats tree leaves tree camouflages moth; benefit - no difference tree 3. other acceptable ones	(hi) Can you see any other combined relationships in our oak tree ecosystem? example: 1. squirrel vs. chipmunk moves acorns around spreading seeds - mutual benefit competitive tree 2. robin $\xrightarrow[\text{prey}]{\text{predator}}$ moth nesting benefit - no difference moth eats tree leaves tree camouflages moth; benefit- no difference tree 3. other acceptable ones	praise "no" + reason prompt on board: diagram of the relationship	neutral "no" probe
Now let's see if a combined relationship fits our definition of a relationship.					

St+	St-	Sc+	Sc-	Rc+	Rc-
		(hi) What are the parts that make up a combined relationship? simpler relationships	(lo) Since a combined relationship has simpler relationships for its parts, does a combined relationship fit the need for at least 2 parts in the general definition of a relationship? yes	praise "no" + reason prompt on board	neutral "no" probe
		(hi) Does one simple relationship in a combined relationship have an effect on another simple relationship in the combined relationship? How? 1. yes 2. any correct answer from the examples given; e.g., a change in the nesting relationship between robins and the oak tree would change the amount of leaves of the tree eaten by moths	(hi) Does one simple relationship in a combined relationship have an effect on another simple relationship in the combined relationship? How? 1. yes 2. any correct answer from the examples given; e.g., a change in the nesting relationship between robins and the oak tree would change the amount of leaves of the tree eaten by moths	praise "no" + reason prompt	neutral "no" probe
So the combined relationship fits the general description of a relationship in ecology - it has 2 parts (at least) and one part affects the other.					

251

St+	St-	Sc+	Sc-	Rc+	Rc-
Let's get away from relationships for a little while to see what we mean by an ecosystem. Remember, I said we'd have to look at what a system really is.					
		(lo) What did it say in the reading about the characteristics of a system? 1. it has several parts 2. all parts are related	(lo) What did it say in the reading about the characteristics of a system? 1. it has several parts 2. all parts are related	praise "no" + reason prompt on board	neutral "no" probe
		(hi) Is a combined relationship an example of a system? How? 1. yes 2. has several parts (relations) 3. all are related so that a change in one part leads to a predictable change in another part	(lo) Does a combined relationship have several parts? yes	praise "no" + reason prompt	neutral "no" probe
			(lo) Does a change in one part of a combined relationship lead to a predictable change in another part of the combined relationship? (Use example from before) yes	praise "no" + reason prompt	neutral "no" probe

252

St+	St-	Sc+	Sc-	Re+	Re-
			(1o) A system involves parts related in an orderly way. We just showed that a combined relationship has parts related in an orderly way. What does that make a combined relationship? a system	praise "no" + reason prompt	neutral "no" probe
Systems are defined by the fact that they are orderly arrangements of relationships. This is a very important idea in the word ecosystem. on board: ecosystem	Systems are defined by the fact that they are orderly arrangements of relationships.				
The relationships must be connected in ways that allow us to predict what happens to other parts in the system if one part changes. We call this kind of condition where we can predict changes, a lawful system. on board: lawful	The relationships must be connected in ways that allow us to predict what happens to other parts in the system if one part changes. We call this kind of condition where we can predict changes, a lawful system.				

253

St+	St-	Sc+	Sc-	Rc+	Re-
		(hi) Is our miniature oak tree ecosystem a real system? Why? 1. yes 2. has parts that are relations 3. lawful	(lo) Does our miniature oak tree ecosystem have parts that are relations? yes	praise "no" + reason prompt	neutral "no" probe
			(lo) And haven't we shown how they are lawful? yes	praise "no" + reason prompt	neutral "no" probe
			(lo) So what does this make our miniature ecosystem? a system	praise "no" + reason prompt	neutral "no" probe
We call the study of a lawful system a <u>science</u>. on board: <u>science</u> Since ecology studies lawful relationships in ecosystems, it is a science.	We call the study of a lawful system a science. Since ecology studies lawful relationships in ecosystems, it is a science.				

254

St+	St-	Sc+	Sc-
Let's review for a moment what we've covered in today's lesson: 1. ecosystems involve a. parts - living things, non-living things that are related b. the relationships are lawful 2. 5 important kinds of relationships a. predator-prey(ex) b. benefit - no difference(ex) c. mutual benefit (ex) d. competitive (ex) e. combined (ex) 3. ecology is a <u>science</u> it looks for lawful relationships between living things and non-living things that are true in general.			

St+	St-	Sc+
Let's start with a review of yesterday's lesson. 1. Ecosystems Involve a. Parts - living things, non-living things, and relationships between them. b. The relationships are lawful. 2. We saw 5 major kinds of relationships. a. Predator - prey (ex) b. Benefit-no diff (ex) c. Mutual benefit (ex) d. Competitive (ex) e. Combined (ex) 3. Ecology is a science. It looks for lawful relations that make up systems of living and non-living things. OK - Now that we've reviewed yesterday's lesson, let's look at our objectives for today.		

Lesson II. Energy in the Ecosystem

St+	St-	Sc+	Sc-
The objectives of today's lesson are: 1. Look at a. Kinds of energy. b. Producers and users of energy. c. Energy and ecological relationships 2. Also discuss how potential energy is changed to kinetic energy. 3. Role of energy in the Ecosystem.			
Before we get into a discussion of the material, I'll outline exactly what we'll be talking about. (On Board) Energy 1. Kinetic 2. Potential 3. Releasing action Energy flow 1. Producers - Photosynthesis 2. Consumers 3. Oxidation			

St+	St-	Sc+	Sc-	Re+	Re-
OK - Now that I've outlined the material and you know what we'll be talking about, let's get to the first topic.					
"What is energy?" It is very important in the study of ecology. Energy is defined as "The ability to engage in action" Energy is not the action itself, but the ability to engage in it.	The definition of energy is: "The ability to engage in action" Energy is not the action itself, but the ability to engage in it.				
		(Lo) What are some examples of energy that were mentioned in your reading? Running; growing; eating acorns, pinenuts, etc.	(Lo) What are some examples of energy that were mentioned in your reading? Running; growing; eating acorns, pinenuts, etc.	Praise "no" + reason Prompt On Board	Neutral "no" Probe

St+	St-	Sc+	Sc-	Rc+	Re-
Energy plans an important role in relationships. E.g., when hawks eat rabbits they are getting food, which provides them with energy for future action.	We can see energy in relationships. E.g., when hawks eat rabbits they are getting food, which provides them with energy for future action.				
		(Lo) Hawks eating rabbits is an example of what kind of relationship? Predator - prey	(Lo) Hawks eating rabbits is an example of what kind of relationship? Predator - prey	Praise "no" + reason Prompt On Board	Neutral "no" Probe
		(Lo) What are two other simple relationships we talked about and read about yesterday? Mutual benefit Benefit - No difference	(Lo) What are two other simple relationships we talked about and read about yesterday? Mutual benefit Benefit - No difference	Praise "no" + reason Prompt On Board	Neutral "no" Probe
One of the benefit - no difference relationships we talked about yesterday was a vine climbing up a tree. The vine was getting energy from the sun by the aide of the tree. The lichen was an example of a mutual benefit relationship. The algae made a sap for the fungi to eat. And the fungi provided water for the algae. In both cases materials necessary for energy were involved.	One kind of benefit - no difference is a vine climbing up a tree. The vine gets energy from the sun by the aide of the tree. A lichen is an example of a mutual benefit relationship. The algae makes a sap for the fungi to eat. And the fungi provides water for the algae. In both cases materials necessary for energy are involved.				

259

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Hi) What is another example of a mutual benefit relationship?	(Lo) How is energy involved in the benefit - No Difference relationship of the vine and tree? Vine obtains energy from sun.	Praise "no" + reason Prompt On Board	Neutral "no" Probe
		(Hi) How is energy involved in this example?	(Lo) Does fungi obtain energy from algae in a lichen? How? Yes - eating sap made by algae.	Praise "no" + reason Prompt On Board	Neutral "no" Probe
		(Hi) Does a predator - prey relationship always involve energy? Why? Yes	(Lo) Predator - prey relationships always involve energy. In the example I gave, how did the hawk get energy? Eating rabbits	Praise "no" + reason Prompt On Board	Neutral "no" Probe
Let's briefly summarize: 1. Energy is the ability to engage in action. 2. Energy is involved in other ecological relationships, like predator - prey, and benefit - No Difference relationships.	Another example of how energy is involved in a predator - prey relationship is robins eating moths. Robin obtains energy from moth. Another example of energy and a benefit - No Difference relationship is seagulls and humans. Seagulls eat garbage from humans, thus getting energy without either benefitting or harming humans.				

260

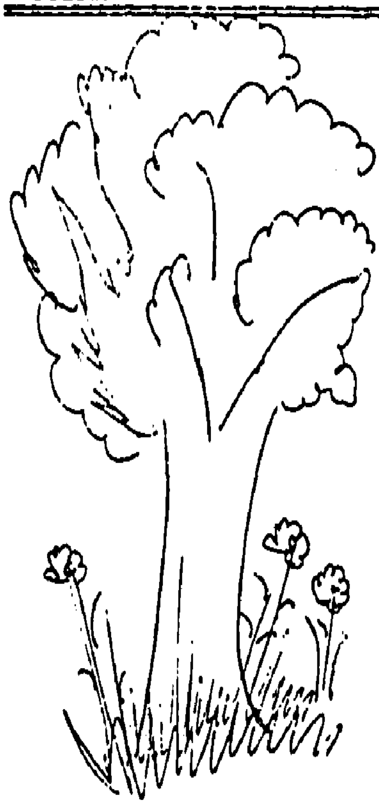
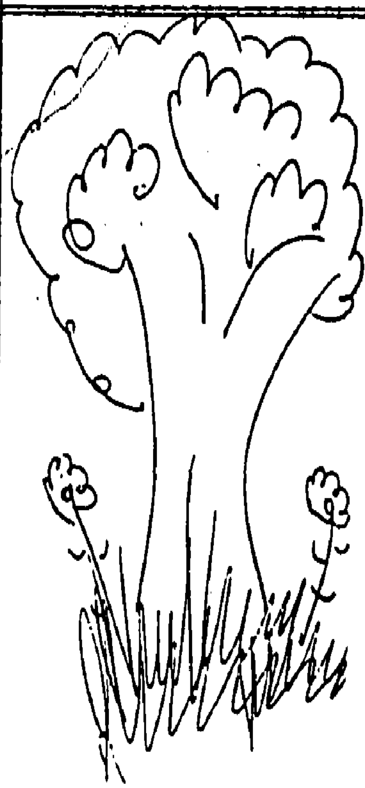
St+	St-	Sc+	Sc-	Rc+	Re-
Now let's get on to the next topic. Let's talk about the two kinds of energy and how one gets changed to the other.					
		(Lo) What are the two kinds of energy that were mentioned in the reading? Kinetic Potential	(Lo) What are the two kinds of energy that were mentioned in the reading? Kinetic Potential	Praise "no" + reason Prompt On Board	Neutral "no" Probe
		(Hi) Do all animals use kinetic energy? If so, how do they use kinetic energy?	(Lo) What kind of energy is kinetic energy. How do we know it is present. From action - When things are active.	Praise "no" + reason Prompt On Board	Neutral "no" Probe
		(Hi) Do all plants use kinetic energy? How? Yes, growing, etc.	(Lo) What are some examples of kinetic energy? Walking, running, breathing.	Praise "no" + reason Prompt On Board	Neutral "no" Probe
All living things use kinetic energy, even if it is only used to move things around inside it, like water in a plant, or blood in an animal.	All living things use kinetic energy, even if it is only used to move things around inside it, like water in a plant, or blood in an animal.				

261

St+	St-	Sc+	Sc-	Re+	Re-
Animals and plants get their kinetic energy from their stored potential energy. We've said that animals get energy by eating.	Animals and plants get their kinetic energy from their stored potential energy.	(Lo) What is the definition of potential energy? Stored	(Lo) What is the definition of potential energy? Stored	Praise "no" + reason Prompt On Board	Neutral "no" Probe
			(Lo) What kind of energy is present in a walnut lying on the ground? Potential	Praise "no" + Reason Prompt On Board	Neutral "no" Probe
		(Hi) How do you think potential energy gets changed to kinetic energy? Ex. Concept of releasing action. Some kind of chemical process, may include digestion	(Hi) How do you think potential energy gets changed to kinetic energy? Ex. Concept of releasing action. Some kind of chemical process, may include digestion.	Praise "no" + reason Prompt On Board	Neutral "no" Probe
All potential energy used by plants and animals must be changed to kinetic energy by a releasing action. In all living things this releasing action is always the addition of oxygen to the potential energy. We call this oxidation.	All potential energy used by plants and animals must be changed to kinetic energy by a releasing action. In living things, this releasing action is always the addition of oxygen to the potential energy. We call this oxidation.				
		(Lo) How do plants change their stored potential energy to kinetic energy? Releasing action, Oxidation	(Lo) How do plants change their stored potential energy to kinetic energy? Releasing action, Oxidation	Praise "no"+ reason Prompt On Board	Neutral "no" Probe

St+	St-	Sc+	Sc-	Re+	Re-
		(Lo) How do animals change potential energy to kinetic energy? Oxidation	(Lo) How do animals change potential energy to kinetic energy? Oxidation	Praise "no" + reason Prompt On Board	Neutral "no" Probe

263

St+	St-	Sc+	Sc-
Let me summarize what we've said about the 2 kinds of energy. 1. Kinetic - action 2. Potential - stored 3. Potential changed to kinetic through releasing action (oxidation).	All living things change potential energy into kinetic energy by oxidation. This is true of plants and animals. Even humans change potential energy to kinetic energy through oxidation.		
To introduce the next topic I'm going to put a familiar picture on the board.			
			

St+	St-	Sc+	Sc-	Rc+	Rc-
Oak tree Lichen < algae, fungi Birds - robin, sparrow, woodpecker, wren, bluebird. Mammals - squirrel, chipmunk, gopher. Insects - caterpillar, grubs (in bark), moth, bee. Other plants - flowers, climbing vines, grass.	Oak tree Lichen < algae, fungi Birds - robin, sparrow, woodpecker, wren, bluebird. Mammals - squirrel, chipmunk, gopher. Insects - caterpillar, grubs (in bark), moth, bee. Other plants - flowers, climbing vines, grass.				
When we talked about this tree and the living things around it yesterday, we saw that there were many different relationships present in this example.	There are many different relationships present in this example.				
		(Lo) What were the five different relationships we talked about with this example? Predator - prey Mutual benefit Benefit - No Difference Competitive Combined	(Lo) What were the five different relationships we talked about with this example? Predator - prey Mutual benefit Benefit - No Difference Competitive Combined	Praise "no"+ reason Prompt On Board	Neutral "no" Probe

265

St+	St-	Sc+	Sc-	Rc+	Re-
		(Lo) What are examples of each of the five relationships?	(Lo) What are examples of each of the five relationships?	Praise "no"+ reason Prompt On Board	Neutral "no" Probe
		1. Predator - prey: a. Robin - caterpillar, moth. b. Woodpecker - grubs. c. Bluejay - caterpiller moth.	1. Predator - prey: a. Robin - caterpillar, moth. b. Woodpecker - grubs. c. Bluejay - caterpillar moth.		
		2. Benefit - No Difference: a. Squirrel nest - tree b. Moth - tree (as camouflage) c. Birds' nests - tree d. Climbing vine - tree	2. Benefit - No Difference: a. Squirrel nest - tree b. Moth - tree (as camouflage) c. Birds' nests - tree d. Climbing vine - tree		
		3. Mutual benefit: a. Bee - flower b. Squirrel - tree (spreads seeds) c. Lichen - algae provides sap for fungi which collects water.	3. Mutual benefit: a. Bee - flower b. Squirrel - tree (spreads seeds) c. Lichen - algae provides sap for fungi which collects water.		
		4. Competitive: a. Squirrel, chipmunk - acorns. b. Robin, bluejay - moth or caterpillar. c. Moth, caterpillar - tree leaves. d. Wren, bluebird - woodpecker holes for nest	4. Competitive: a. Squirrel, chipmunk - acorns. b. Robin, bluejay - moth or caterpillar. c. Moth, caterpillar - tree leaves. d. Wren, bluebird - woodpecker holes for nest		
		5. Combined: a. Robin - moth, moth - tree, robin - tree. b. Squirrel - tree, Squirrel vs. chipmunk - acorn, tree (as nest) - squirrel.	5. Combined: a. Robin - moth, moth - tree, robin - tree. b. Squirrel - tree, squirrel vs. chipmunk - acorn, tree (as nest) - squirrel.		

266

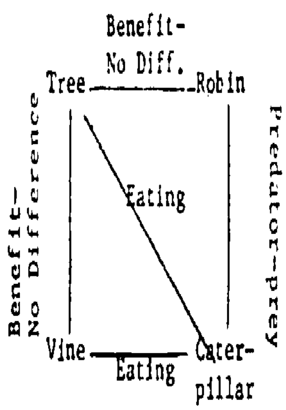
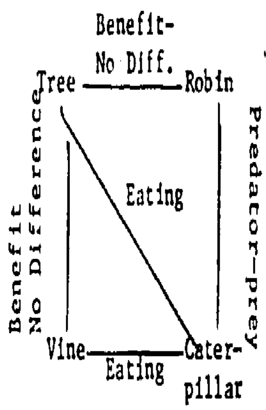
St+	St-	Sc+	Sc-	Rc+	Rc-
We're going to come back to these examples in a minute. But first we'll talk about two important topics concerning energy and ecology.	Animals get their energy from eating plants and other animals. But plants generally do not eat other things for food.				
		(Lo) How do plants get their food? Make it.	(Lo) How do plants get their food? Make it.	Praise "no" + reason Prompt On Board	Neutral "no" Probe
		(Hi) If there were some mushrooms growing under the oak would they be making their own food? Why? Why not? No - not green, no photosynthesis.	(Lo) What is the chemical process called that plants use to make food? Photosynthesis	Praise "no" + reason Prompt On Board	Neutral "no" Probe
		(Hi) If you planted seeds from Foothill grasses deep in a cave where the sun never shined, would they grow to maturity? Why not? They are photosynthesizers and need sunlight	(Lo) What things have to be present for plants to photosynthesize, that is, to make their food? Energy (sunlight), water, carbon dioxide, chlorophyll.	Praise "no" + reason Prompt On Board	Neutral "no" Probe
		(Hi) What if you planted mushrooms there. Would they grow? Yes they could, provided they had stuff to grow on. They don't need the sunlight.	(Lo) Can animals make their own food? Why not? No - can't photosynthesize.	Praise "no" + reason Prompt On Board	Neutral "no" Probe

267

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Lo) Since plants make their own food, what name have we given them? Producers	(Lo) Since plants make their own food, what name have we given them? Producers	praise "no" + reason prompt On Board	neutral "no" probe
		(Lo) What do we call animals, since they have to eat other animals and plants to get their food? Consumers	(Lo) What do we call animals, since they have to eat other animals and plants to get their food? Consumers	praise "no" + reason prompt On Board	neutral "no" probe
		(Lo) Are all plants producers? No	(Lo) Are all plants producers? No	praise "no" + reason prompt On Board	neutral "no" probe
		(Lo) Can you give examples of plants that are not producers? Mushrooms, other non-green plants, fungus	(Lo) Can you give examples of plants that are not producers? Mushrooms, other non-green plants, fungus	praise "no" + reason prompt On Board	neutral "no" probe
		(Hi) A Venus fly trap is a green plant that eats flies by catching them in special pods. Is it a producer or a consumer? Why? Both	(Hi) A Venus fly trap is a green plant that eats flies by catching them in special pods. Is it a producer or a consumer? Why? Both	praise "no" + reason prompt On Board	neutral "no" probe

St+	St-	Sc+	Sc-	Re+	Re-
Briefly summarizing, their are two important points here. Some plants (green ones) make their own food. These plants are called producers. Other things (animals and non-green plants) must eat other things for food. These are called consumers.	There are other plants besides the Venus Fly trap that are both producers and consumers, but generally they are rare. There are some microscopic, one celled creatures that can make their own food, and they move around like animals. Like the Venus fly trap, they have some characteristics of plants and some characteristics of animals. They are interesting exceptions that make the science of ecology interesting.				
Let's get back to our oak tree example and tie it together with our producer-consumer distinction.					
The relationship between producers and consumers is called ENERGY FLOW. That is because energy flows from the producers to the consumers, not back again.	The relationship between producers and consumers is called energy flow. That is because energy flows from the producers to the consumers, not back again.	(Hi) Which of our five ecological relationships included producers? Benefit - no difference Mutual benefit Competitive Combined	(Lo) The only one of our five ecological relationships that didn't have producers was the predator-prey relationship. That is because all of the living things in predator-prey relationships are___? Animals	praise "no" + reason prompt On Board	neutral "no" probe

269

St+	St-	Sc+	Sc-	Re+	Re-
(On Board) 	(On Board) 				
		(Lo) What are the producers in this example? Tree, vine	(Lo) What are the producers in this example? Tree, Vine	praise "no" + reason prompt On Board	neutral "no" probe
		(Lo) What are the consumers in this example? Robin, caterpillar	(Lo) What are the consumers in this example? Robin, caterpillar	praise "no" + reason prompt On Board	neutral "no" probe

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Hi) Some of our examples of ecological relationships included consumers and producers. Which of our examples included consumer-producer relationships that also were energy relationships? 1. Benefit- no difference: a. climbing vine - tree 2. Mutual benefit: a. lichen 3. Competitive: a. squirrel, chipmunk - acorns b. moth, caterpillar - tree, leaves 4. Combined: a. squirrel-tree, squirrel vs. chipmunk-acorns tree -(as nest) squirrel.	(Hi) Some of our examples of ecological relationships included consumers and producers. Which of our examples included consumer-producer relationships that also were energy relationships? 1. Benefit - no difference: a. climbing vine - tree 2. Mutual benefit: a. lichen 3. Competitive: a. squirrel, chipmunk - acorns b. moth, caterpillar - tree, leaves 4. Combined: a. squirrel-tree, squirrel vs. chipmunk-acorns tree - (as nest) squirrel.	praise "no" + reason prompt On Board	neutral "no" probe
		(Hi) What would happen to life on earth if something happened to the atmosphere that cut out all the light units so that plants could not photosynthesize? all life would die off	If something happened that caused all the green plants to stop photosynthesizing (like a total loss of sunlight) all life would die out. The green plant producers are the beginning of all the potential energy for life.	praise "no" + reason prompt On Board	neutral "no" probe

271

St+	St-	Sc+	Sc-
It is very important that you understand that producers are the source of all potential energy for consumers. Whenever producers die off in any area the consumers die off too. If all green plants died in the world, humans would soon die also.	Producers are the source of all potential energy for consumers. Whenever producers die off in any area, the consumers die off, too. If all green plants died in the world, humans would soon die also.		
Summarizing this last part producer-consumer energy relationships play an important part in other ecological relationships, such as mutual benefit, benefit - no difference, competitive, and combined. When you include predator-prey, you can see that energy relationships are very important in all of ecology.	In the foothills, grass is often the first source of potential energy for consumers. Rabbits, mice, gophers, ground squirrels, all eat the grass. These animals are consumers and depend on the green plant producers for food.		

Lesson II. Energy in the Ecosystem

St+	St-	Sc+	Sc-	Rc
Now I'll review the main points of today's lesson. Then we'll be done for today. (On Board) <u>Energy</u> Potential (Define) ↓ Releasing action (Oxidation) Kinetic (Define) <u>Energy Flow</u> Producers (Define) (Photosynthesis) ↓ Consumers (Define)				

St+	St-	Sc+
Before we start today's lesson, let's review what we learned yesterday for a moment. **Energy:** potential (define) ↓ releasing action - oxidation kinetic (define) **Energy Flow:** producers (define) ↓ photosynthesis consumers (define) 351		

Lesson III. The Flow of Energy in the Ecosystem

St+	St-	Sc+	Sc-
Today, we're going to look at energy as it moves or flows through the ecosystem. The goals for today's lesson are: 1. describe the energy flow 2. examine the way energy is transferred and what this means to the way the ecosystem operates 3. learn about the very important principle of conservation of energy			
To start us out, I'll outline what we'll look at in this lesson. 1. all life requires 2 things a. matter - we'll look at this tomorrow b. energy 2. energy is of 2 kinds a. potential - stored b. kinetic, which involves (1) activity plus (2) heat			

St+	St-	Sc+	Sc-	Re+	Re-
3. 2 basic characteristics of energy flow in the ecosystem a. unidirectionality b. conservation (1) we'll see the important place of heat in this major principle 4. new terms for today include: a. unidirectionality b. food chain c. multi-level consumers d. energy pyramid					
Let's begin with some questions to get basic information into our discussion.	Today we're going to look at the flow of energy through the ecosystem.				
		(1o) What is energy? the ability to do things to engage in activity	(1o) What is energy? the ability to do things, to engage in activity	praise "no" + reason prompt on board: energy→ activity	neutral "no" probe

St+	St-	Sc+	Sc-	Re+	Re-
		(lo) What are the 2 kinds of energy? 1. kinetic 2. potential	(lo) What are the 2 kinds of energy? 1. kinetic 2. potential	praise "no" + reason prompt on board: kinetic poten-tial	neutral "no" probe
		(hi) How are these two kinds of energy alike and how are they different? 1. alike - both have a relation to action, activity 2. different - a. kinetic energy is energy <u>in</u> use b. potential energy is energy <u>stored</u> for later use	(lo) Since kinetic energy and potential energy are both energy, what ability or characteristic do they share? both are related to action	praise "no" + reason prompt on board (from above): kinetic= in use poten-tial= stored for later use	neutral "no" probe
			(lo) What do living things do with kinetic energy? use it for activity	praise "no" + reason prompt on board (above)	neutral "no" probe
			(lo) And if kinetic energy is energy used by living things for action, what is potential energy? stored for later use	praise "no" + reason prompt on board (above)	neutral "no" probe

277

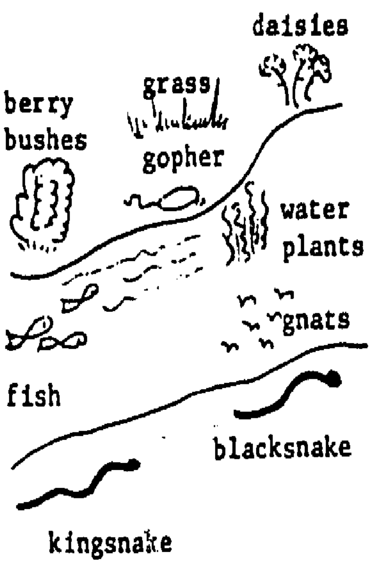
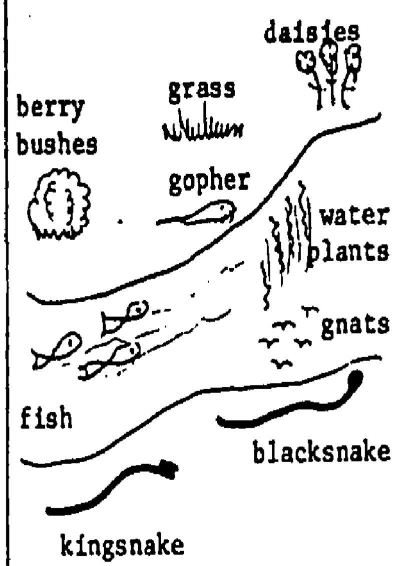
St+	St-	Sc+	Sc-	Rc+	Rc-
Now since potential energy is stored up and kinetic energy is energy that is being used, there has to be something that changes stored energy into useful energy. We call that something a releasing action. on board: releasing action	Now since potential energy is stored up and kinetic energy is energy that is being used, there has to be something that changes stored energy into useful energy. We call that something a releasing action.				
		(1o) What's an example of a releasing action? oxidation	(1o) What's an example of a releasing action? oxidation	praise "no" + reason prompt	neutral "no" probe
Now that we're warmed up to energy and some of its characteristics, let's look more closely at kinetic energy.					

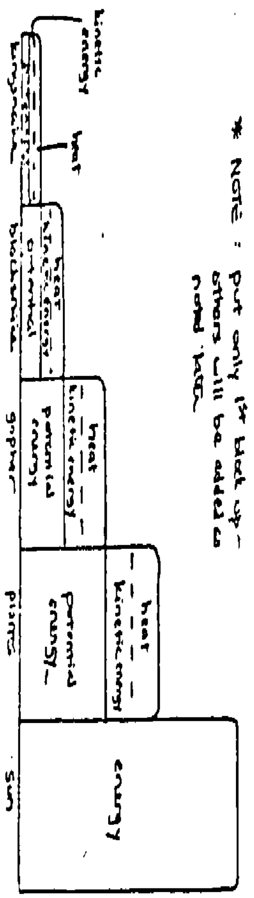
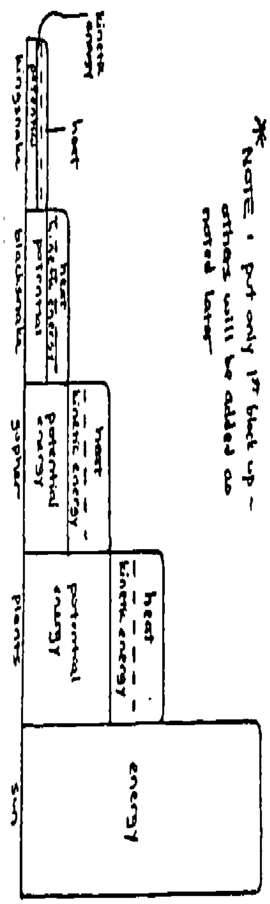
St+	St-	Sc+	Sc-
Kinetic energy is energy in things that are active. Whenever there is action or activity, there is kinetic energy involved. There's also something besides activity whenever kinetic energy is present, however, heat. Any activity results in some heat. You notice heat most when there is a lot of activity, like when you get warm after running. You've also seen the relation between heat and activity when you rub your hands together when they're cold. But heat is also given off during hardly noticeable activities like breathing, digesting food, looking for food by shopping like you do or by hunting like animals do, and so on.	Kinetic energy is energy in things that are active. Whenever there is action or activity, there is kinetic energy involved. There's also something besides activity whenever kinetic energy is present, however, heat. Any activity results in some heat. You notice heat most when there is a lot of activity, like when you get warm after running. You've also seen the relation between heat and activity when you rub your hands together when they're cold. But heat is also given off during hardly noticeable activities like breathing, digesting food, looking for food by shopping like you do or by hunting like animals do, and so on.		

St+	St-	Scr	Sc-	Re+	Re-
We could picture this relation like this: on board: kinetic energy activity heat This shows how heat is always involved when kinetic energy is used to be active and given off.	We could picture this relation like this: on board: kinetic energy activity heat				
		(hi) What's the difference between potential energy and heat? 1. potential energy is stored for later use in activity 2. heat is given off during activity	(lo) What is the basic characteristic of potential energy? stored for later use in activity	praise "no" + reason prompt	neutral "no" probe
			(lo) What did we say about heat and activity? What happens to heat? it is given off	praise "no" + reason prompt	neutral "no" probe
Heat energy is lost from the ecosystem - it can't be used by another living thing	Heat energy is lost from the ecosystem - it can't be used for another living thing				

280

364

<table>
<tr><th>St+</th><th>St-</th><th>Sc+</th><th>Sc-</th></tr>
<tr><td>Let's use these ideas about kinetic energy, activity, heat, and potential energy to see how energy moves through or <u>flows</u> through parts of the ecosystem.</td><td></td><td></td><td></td></tr>
<tr><td>Here's some living things that live around a stream in the ecosystem.
</td><td>Here's some living things that live around a stream in the ecosystem.
</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>

St+	St-	Sc+	Sc-	Ro+	Ro-
		What's the source of (lo) energy for the living things here? sun	What's the source of (lo) energy for living things here? sun	praise "no" + reason prompt	neutral "no" probe
We can represent all the energy that the sun provides to the plants by the following diagram: 	We can represent all the energy that the sun provides to the plants by the following diagram: 	(hi) What do plants do with the energy they get from the sun? 1. some used for life activities 2. rest stored in plant materials (stem, leaves)	(lo) What are some activities that the plants use the sun's energy for? growing, photosynthesis, any activity	praise "no" + reason prompt	neutral "no" probe
			(lo) What kind of energy do we call the rest of the sun's energy which is stored in the plant's stems and leaves? potential energy	praise "no" + reason prompt	neutral "no" probe

282

387

386

St+	St-	Sc+	Sc-	Rc+	Rc-
Now that some of the sun's energy has been converted to kinetic energy - activity and heat - that energy is not in the plant's parts. So the energy available to a gopher who eats the plant's roots is less than all the energy the plant received from the sun. Our picture now looks like this:	Now that some of the sun's energy has been converted to kinetic energy, that energy is not in the plant's parts. So the energy available to a gopher who eats the plant's roots is less than all the energy the plant received from the sun. Our picture now looks like this:				
(add plant block to diagram)	(add plant block to diagram)				
		(hi) Does the gopher use energy in the same general way as the plant did? How? 1. yes 2. some used for life activities, some stored in muscle, bone, etc.	(lo) When the gopher does things, does it use kinetic energy? yes	praise "no" + reason prompt	neutral "no" probe
			(lo) What kind of energy is stored up in the gopher's muscle, fat, bone, etc. potential energy	praise "no" + reason prompt	neutral "no" probe

283

St+	St-	Sc+	Sc-	Ru-
The gopher now has gotten all the potential energy that was in the plant, converted some of it into potential energy stored in its body, and used some in activity that also produced heat. The picture of energy flowing through the ecosystem now looks like this: (add gopher block to diagram)	The gopher now has gotten all the potential energy that was in the plant, converted some of it into potential energy stored in its body, and used some in activity. The picture of energy flowing through the ecosystem now looks like this: (add gopher block to diagram)			
After the gopher eats the plants, he has an unfortunate accident. He's eaten by the blacksnake.	After the gopher eats the plants, he has an unfortunate accident. He's eaten by the blacksnake.			

St+	St-	Sc+	Sc-	Rt+	Re-
		(hi) What do you think happens to the energy the blacksnake gets from the gopher? 1. some used for activity, energy lost as heat 2. some stored as potential energy	(lo) Does the blacksnake use up some of the energy from the gopher when it engages in life activities? yes	praise "no" + reason prompt	neutral "no" probe
			(lo) And what kind of energy is stored up in the blacksnake that was part of all the energy it got from the gopher? potential energy	praise "no" + reason prompt	neutral "no" probe
So, from the chain of events from the sun to the plant to the gopher to the blacksnake, the movement or flow of energy now looks like this: (add blacksnake block to diagram)	The picture of energy flow now looks like this: (add blacksnake block to diagram)				

285

St+	St-	Sc+	Sc-
Since the blacksnake is fat and lazy with its big gopher lunch, along comes a hungry kingsnake. The kingsnake is one of the few snakes that eats other snakes. The blacksnake becomes a meal for the kingsnake and the potential energy stored in the blacksnake is now transferred to the kingsnake. Like the other living things before it, the kingsnake uses some of the energy gained from the blacksnake for living activities. The remainder is stored as potential energy in fat, muscle, blood and other body materials. Our energy picture now looks like this: (add kingsnake block to diagram)	Since the blacksnake is fat and lazy with its big gopher lunch, along comes a hungry kingsnake. The kingsnake is one of the few snakes that eats other snakes. The blacksnake becomes a meal for the kingsnake and the potential energy stored in the blacksnake is now transferred to the kingsnake. Like the other living things before it, the kingsnake uses some of the energy gained from the blacksnake for living activities. The remainder is stored as potential energy in fat, muscle, blood, and other body materials. Our energy picture now looks like this: (add kingsnake block to diagram)		

St+	St-	Sc+	Sc-	Rc+	Rc-
So we now have a chain of the parts in the ecosystem through which energy flows. A <u>food chain</u>.	The whole flow is a food chain.				
		(hi) If we wanted to describe the flow of energy in any ecosystem, what names would we give to the parts of the food chain that energy flows through? What's an example of each? 1. producers - plants 2. 1st order consumers - muskrat 3. 2nd order consumers - blacksnake 4. 3rd order consumers - kingsnake	(lo) What name do we give to the first part of the ecosystem, the plants, through which energy flows? producers	praise "no" + reason prompt on board: producers 1st order consumer, etc.	neutral "no" probe
			(lo) What about the next part through which energy passes, the rabbit in your reading, or the gopher in this example? 1st order consumer	praise "no" + reason prompt on board	neutral "no" probe
			(lo) And what is the next part, the fox in the reading, or the blacksnake here? 2nd order consumer	praise "no" + reason prompt on board	neutral "no" probe
			(lo) How about the next part - the hawk in the reading or the kingsnake in our example? 3rd order consumer	praise "no" + reason prompt on board	neutral "no" probe

287

St+	St-	Sc+	Sc-	Rc+	Rc-
Up to now, we've looked at what happened to energy as it flows through the eco-system. Let's focus on the living things for a moment.					
		(hi) Suppose a second kingsnake came along and ate the first kingsnake. Would kingsnakes be 3rd order consumers or 4th order consumers? Why? The kingsnake population is both 3rd order con-sumers and 4th order consumers	(hi) Suppose a second kingsnake came along and ate the first kingsnake. Would kingsnakes be 3rd or 4th order consumers? Why? The kingsnake population is both 3rd order con-sumers and 4th order consumers	praise "no" + reason prompt	neutral "no" probe
When this happens, that is, when the same kind of living thing enters the energy flow at more than one level, it is called a <u>multi-level</u> <u>consumer</u>. on board: <u>multi-level</u> <u>consumer</u>	When this happens, that is, when the same kind of living thing enters the energy flow at more than one level, it is called a multi-level consumer.				

288

376

377

St+	St-	Sc+	Sc-	Re+	Re-
		(hi) Can you think of other examples of multi-level consumers? Why is this a multi-level consumer? 1. accept any answer; for example, birds eat seeds as 1st order consumers, bugs as 2nd order consumers 2. because it appears at more than one level in the flow of energy	(lo) A bird can be a 1st order consumer by eating seeds and a 2nd order consumer by eating insects. Also, the bird can be called a 3rd order consumer because some of the insects it eats have eaten other insects. Is this bird a multi-level consumer? yes	praise "no" + reason prompt on board	neutral "no" probe
OK, let's get back to focusing on energy. Remember the reading said energy flow in the ecosystem was uni-directional. on board: unidirectional					

289

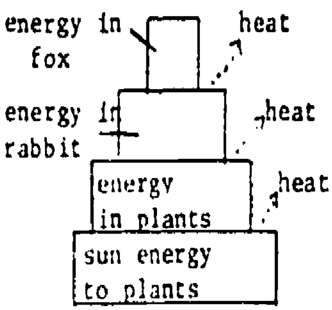
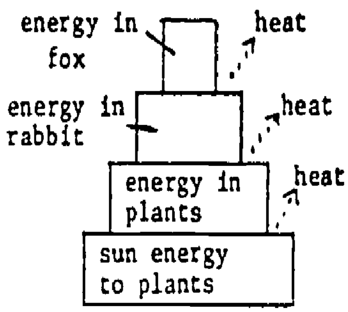
St+	St-	Sc+	Sc-	Rc+	Rc-
		(hi) Is energy flow unidirectional when multi-level consumers are in the energy flow? Why? 1. yes 2. because energy flows from producers to 1st order consumers to 2nd order consumers to 3rd order consumers, and so on down the line.	(lo) When a multi-level consumer enters the energy flow but we still describe energy flow as moving from producers to 1st order consumers, to 2nd order consumers and to 3rd order consumers, and so on down the line, is energy flow unidirectional? yes	praise "no" + reason prompt	neutral "no" probe
Just because an organism enters the flow of energy more than once doesn't change the principle that energy flows in a unidirectional pattern.					
This is one characteristic of ecology as a science - it tries to describe ecosystems in ways that the descriptions are true in general.	This is one characteristic of ecology as a science - it tries to describe ecosystems in ways that the descriptions are true in general.				

290

331

St+	St-	Sc+	Sc-
Energy flows in only one direction. It does not flow backwards. This is called <u>unidirectionality.</u> Even though multi-level consumers may enter the energy flow at 2 places, energy flows from the sun to producers to 1st order consumers to 2nd order consumers, and so on down the line. At each exchange of energy, there is always a little less useful energy than there was before.	Energy flows in only one direction. It does not flow backwards. This is called unidirectionality. Even though multi-level consumers may enter the energy flow at 2 places, energy flows from the sun to producers to 1st order consumers to 2nd order consumers, and so on down the line. At each exchange of energy, there is always a little less energy than there was before.		

St+	St-	Sc+
Up to this point, we've looked at the flow of energy in general. It involved the sun, producers, consumers, heat loss, and so on. Let's turn now to seeing how much energy gets transferred to different parts of the ecosystem.		
There's a neat way to picture how much energy is transferred to each living thing next in line in the ecosystem. It's called an energy pyramid. on board: energy pyramid	There's a neat way to picture how much energy is transferred to each living thing next in line in the ecosystem. It's called an energy pyramid.	
Here's what one looks like		

St+	St-	Sc+	Sc-
On board: 	On board: 		
This diagram shows how much energy is lost for use by living things at each level. The heat cannot be transferred to another living thing to be used for life activities.	This diagram shows how much energy is lost for use by living things at each level. The heat cannot be transferred to another living thing to be used for life activities.		

St+	St-	Sr+	Sr-	Re+	Re-
Remember I said we'd learn about 2 important characteristics of energy in the ecosystem today? We've already seen one - the unidirectionality of energy flow. Now let's look at the other.					
In the energy flow, everytime there was activity, heat was given off. This heat could not be used by another living thing.	In the energy flow, everytime there was activity, heat was given off. This heat could not be used by another living thing.	(hi) If you added together the heat given off by a plant, plus the energy used by the plant for life activities, and the potential energy stored in the plant, how much energy would there be altogether? all the sun energy originally in the plant	(hi) If you added together the heat given off by a plant, plus the energy used by the plant for life activities, and the potential energy stored in the plant, how much energy would there be altogether? all the sun energy originally in the plant	praise "no" + prompt	neutral "no" probe
If we add together the heat given off by a plant, the heat given off by a 1st order consumer, the energy used by plants for life activities, and the potential energy stored in the 1st order consumer, we get all the sun energy originally in the plant. We call the principle that the total amount of energy originally in the ecosystem always stays in the ecosystem as either heat or potential energy, the principle of conservation of energy. on board: conservation of energy	If we add together the heat given off by a plant, the heat given off by a 1st order consumer, and the potential energy stored in the 1st order consumer, we get all the sun energy originally in the plant. We call the principle that the total amount of energy originally in the ecosystem always stays in the ecosystem as either heat or potential energy, the principle of conservation of energy.				

294

335 336

St+	St-	Sc+	Sc-
Let's review what we've covered in today's lesson: 1. energy a. kinetic < activity / heat b. potential 2. energy flow through the ecosystem a. unidirectionality-food chain (1) multi-level consumers b. conservation of energy and heat loss 3. energy and weight pyramids 4. saw how ecology was a science because it could describe things so they were true in general for the ecosystem			

St+	St-	St+
Let's take a brief look at what we covered yesterday. 1. Energy a. kinetic< activity / heat b. potential 2. Energy flow through the ecosystem a. unidirectionality-food chain (1) multi-level consumers b. conservation of energy and heat loss 3. Energy and weight pyramids 4. Saw how ecology was a science because it could describe things so that they were true in general for the ecosystem.		

St+	St-	Sc+	Sc-
In today's lesson we're going to talk about matter and how it moves through the environment. There are 3 major objectives for today's lesson: 1. to learn the concept of cycles as it relates to matter. Then, we'll see that matter is always in our environment because it cycles through parts of the environment. 2. to describe 4 major types of matter cycles important in the environment 3. to learn about the role of producers, consumers, and decomposers in matter cycles and show how these 3 actors are different in the different matter cycles.			
Let's start out the lesson by outlining the material we'll be covering.			

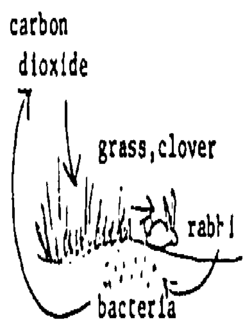
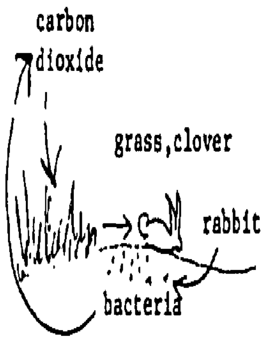
St+	St-	Sc+	Sc-
1. Matter - what is it? 2. What is a cycle? a. what does re-cycle mean? 3. 4 major matter cycles a. carbon } in your b. nitrogen } reading c. water d. mercury 4. 3 kinds of actors in matter cycles and differences between them a. producers b. consumers c. decomposers 5. we'll develop a generalized matter cycle that describes the way most materials move through the environment			
Let's begin with a very important idea. On Board: <u>matter</u>	On Board: matter		

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Lo) What does this word mean? any substance - solid, liquid, or gas - that occupies or takes up space	(Lo) What does this word mean? any substance - solid, liquid, or gas - that occupies or takes up space	praise "no" + reason prompt	neutral "no" probe
		(Lo) What are some examples of matter? Why is that matter? ...anything acceptable	(Lo) What are some examples of matter? Why is that matter? ...anything acceptable	praise "no" + reason prompt	neutral "no" probe
So that we see that matter is anything that takes up space. It can be a gas, a liquid, or a solid. These are the forms of matter. On board: (near matter) gas liquid solid } forms of matter It's also very important to remember that all living things are made up of matter of all 3 types or forms	All living things are made up of matter of all 3 types or forms.				
		(Hi) What's the basic difference between matter and energy? matter takes up space--energy doesn't	(Lo) Does energy take up space? no So a basic difference between matter and energy is that energy doesn't take up space.	praise "no" + reason prompt	neutral "no" probe

St+	St-	Sc+	Sc-	Re+	Re-
OK, let's move on to another very important definition in today's lesson: on board: recycle	On board: recycle				
		(Lo) What are some of the things that we recycle? paper, bottles, cans	(Lo) What are some of the things that we recycle? paper, bottles, cans	praise "no"+ reason prompt	neutral "no" probe
		(Hi) Why do we recycle matter like aluminum? so the matter can be used over again because there is a limited amount of aluminum on the earth	(Lo) Is there an infinite or never-ending supply of matter like aluminum? no	praise "no" + reason prom t	neutral "no" probe
			(Lo) Do we use the same matter over again when we recycle because there is a limited supply of matter, like aluminum, on earth? yes	praise "no" + reason prompt	neutral "no" probe

St+	St-	Sc+	Sc-	Re+	Re-
OK - we see that when we recycle matter we use it over again. The word 'recycle' is made up of the word cycle, meaning round, and the prefix re which means again. Re-cycle means to go around again, or in the case of matter, to be used again and again.	The word recycle is made up of the word 'cycle', meaning round, and the prefix re which means again. Re-cycle means to go around again, or in the case of matter, to be used again and again.				
Now that we have the general idea of matter being recycled, let's move on to look at a particular cycle of matter in which the chemical element carbon is recycled naturally in the environment. This matter cycle was presented in your reading for today.					
		(Lo) Who can describe the carbon cycle? - general description	(Lo) Who can describe the carbon cycle? - general description	praise "no" + reason prompt	neutral "no" probe

301

St+	St-	Sc+	Sc-	Rc+	Rc-
Here's a diagram of how carbon cycles through the environment.  	 				
		(Lo) What living thing is the producer in this diagram? grass = producer	(Lo) What living thing is the producer in this diagram? grass = producer	praise "no" + reason prompt On board	neutral "no" probe
		(Hi) Why is this the procedure? it changes the inorganic chemical compound of carbon dioxide into an organic compound, sugar in the plant	(Lo) What inorganic compound does the producer change to an organic chemical compound, the sugar in the plant? carbon dioxide	praise "no" + reason prompt On board: inorganic com-pound→ organic com-pound	neutral "no" probe

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Lo) What is the consumer in this diagram? rabbit = consumer	(Lo) What is the consumer in this diagram? rabbit = consumer	praise "no" + reason prompt On Board	neutral "no" probe
		(Hi) Why is the rabbit called the consumer? because it cannot make inorganic carbon into organic carbon, it has to get or consume organic carbon compounds from a carbon producer.	(Lo) Since the rabbit can't make inorganic carbon into organic carbon compounds, where does it get or consume organic carbon compounds? from the producer	praise "no" + reason prompt	neutral "no" probe
		(Hi) Are there any plants that are carbon consumers? Why? 1. yes - mushrooms, fungi 2. because they can't change inorganic carbon into organic compounds	(Lo) Since plants like mushrooms and fungi can't make inorganic carbon into organic carbon compounds, are they carbon consumers too? yes	praise "no" + reason prompt	neutral "no" probe
So in the carbon cycle, green plants are carbon producers and non-green plants and animals are carbon consumers. It's important to remember that not all plants are carbon producers, just green plants.	So in the carbon cycle, green plants are carbon producers and non-green plants and animals are carbon consumers.				

303

St+	St-	Sc+	Sc-	Re+	Re-
Let's talk about the decomposers in the carbon cycle now.					
		(Lo) What is the decomposer in the carbon cycle diagram? bacteria = decomposer	(Lo) What is the decomposer in the carbon cycle diagram? bacteria = decomposer	praise "no" + reason prompt On board	neutral "no" probe
		(Hi) What role does the decomposer play in the carbon cycle? breaks down or decomposes complex organic carbon compounds into inorganic carbon compounds like carbon and carbon dioxide	(Lo) When the decomposers do their job, what do we end up with? carbon	praise "no" + reason prompt	neutral "no" probe
Some of the other kinds of decomposers are snails, slugs, mold, and so on.	Some other kinds of decomposers are snails, slugs, molds, and so on.				
OK, let's review the 3 kinds of actors in the matter cycle of carbon. In the matter cycle there are three actors: <u>producers</u>, <u>consumers</u>, and <u>decomposers</u>. We've just seen the role that each plays in the cycle of matter for carbon. Also, I want to point out a very important distinction between the actors in matter cycles and actors in the flow of energy. (cont'd page 9)					

St+	St-	Sc+	Sc-	Rc
We'll also see an important similarity in matter cycles and energy flow.				
We have used the words producer and consumer when we talked about energy flow in the last 2 lessons. The general idea of a producer is always the same whether we are talking about matter cycles or energy flow. A producer changes something inorganic or not directly useful for life activities into something directly useful for life activities. In the carbon cycle, plants changed the inorganic compound carbon dioxide into an organic compound of carbon, sugar. An energy producer changes sunlight into potential energy stored in organic materials. This was done by green plants by the process of photosynthesis.	We have used the words producer and consumer when talking about energy flow, too. The idea of a producer is always the same whether we are talking about energy flow or matter cycles. A producer changes something inorganic or not directly useful for life activities. An energy producer changes sunlight into potential energy stored in inorganic materials. A matter producer changes inorganic chemical elements and compounds into organic compounds. The reasoning is similar for the idea of a consumer. An energy consumer cannot change sunlight into energy useful for life activities. It has to get or consume this useful energy from an energy producer. A matter consumer has to get or consume organic compounds from a matter producer, since it can't change inorganic chemicals into organic compounds.			

St+	St-	Sc+	Sc-
So plants are the matter producers in the carbon cycle and the energy producer in the energy flow. The important point is what they do - changing things not useful for life into things useful for life. On board: producer: not useful for life → useful for life The reasoning is similar for the idea of a consumer. An energy consumer cannot change sunlight into energy useful for life activities. It has to get or consume this useful energy from an energy producer, that is, a green plant. A matter consumer has to get or consume organic compounds from a matter producer, since it can't change inorganic chemicals into organic compounds. In the carbon cycle diagram, the rabbit is an energy consumer and a matter consumer.	Decomposers in the matter cycle change organic compounds of matter back into inorganic materials so they can be recycled through the producers. But because energy isn't recycled, matter decomposers are simply the last of the energy consumers. On Board: decomposers ↙ ↘ matter decomposers = last consumers of energy So the general picture for matter cycles looks like this: On Board: environment → producers ↑ ↓ decomposers ← consumers And the general picture for energy flow looks like this: On Board: sun → producers → consumers		

Lesson IV. Matter in the Living World

St+	St-	Sc+	Sc-	Rc+

Decomposer in the matter cycle, like the bacteria in the carbon cycle, change organic compounds back into inorganic materials. These inorganic materials are then recycled through the producers. But because energy <u>isn't</u> recycled- it's unidirectional - matter decomposers are simply the last consumers of energy. This is an important point.

On Board:

$$\frac{\text{matter decomposers}}{} = \frac{\text{last consumers}}{\text{of energy}}$$

So the general picture for matter cycles, like the carbon cycle, looks like this:

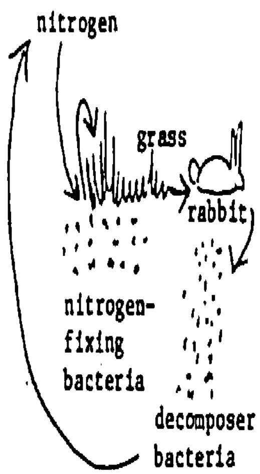
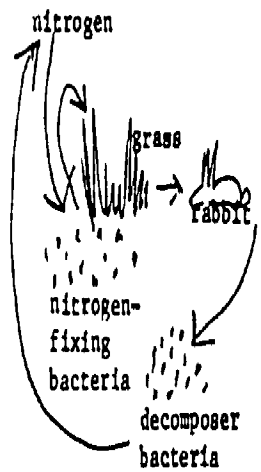
On Board:

$$\begin{tikzcd}
\text{environment} \arrow[r] & \text{producers} \arrow[d] \\
\text{decomposers} \arrow[u] & \text{consumers} \arrow[l]
\end{tikzcd}$$

And the general picture for the energy flow looks like this:

On Board:

sun $\rightarrow$ producers $\rightarrow$ consumers

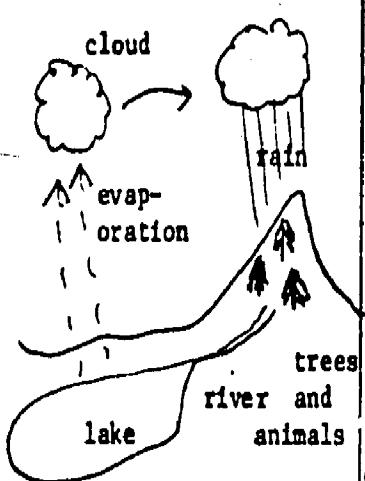
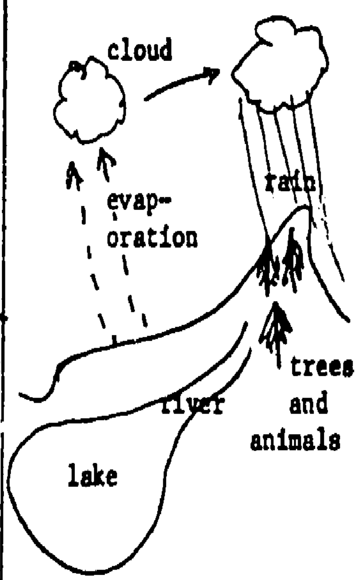
St+	St-	Sc+	Sc-	Re+	Re-
OK - now that we have the distinction between producers and consumers in the energy flow versus producers, consumers, and decomposers in matter cycles, let's turn to another matter cycle - the nitrogen cycle.					
The nitrogen cycle looks like this: On board: 	The nitrogen cycle looks like this: On board: 				
		(Hi) What have we changed in the picture of the nitrogen cycle compared to the picture for the carbon cycle? added nitrogen-fixing bacteria; nitrogen doesn't go directly to grass	(Lo) Since we've added nitrogen-fixing bacteria and drawn the arrow from nitrogen in the air to these bacteria, how is the nitrogen cycle different from the carbon cycle? nitrogen goes to bacteria instead of grass	praise "no" + reason prompt	neutral "no" probe

308

St+	St-	Sc+	Sc-	Rc+	Re-
		(Hi) What are the producers in the nitrogen cycle? Why? 1. nitrogen-fixing bacteria 2. they change nitrogen in the air that can't be used directly for life activities into an organic compound that plants can use	(Lo) The nitrogen-fixing bacteria change inorganic nitrogen in the air into an organic nitrogen compound that the grass can use, so they are called what? matter producers	praise "no" + reason prompt On board: nitrogen fixing bacteria =matter producers	neutral "no" probe
		(Hi) If the nitrogen-fixing bacteria are the matter producers in the nitrogen cycle, what is the grass called? matter consumer	(Lo) Since the plants use nitrogen-fixing bacteria as their source of organic nitrogen, what name would they be given in the cycle? matter consumers	praise "no" + reason prompt On Board grass= matter consumer	neutral "no" probe
So an important difference between the carbon cycle and the nitrogen cycle is that plants are <u>producers</u> in the carbon cycle and <u>consumers</u> in the nitrogen cycle.					
		(Lo) Can you name another consumer? the rabbit	(Lo) Can you name another consumer? the rabbit	praise "no" + reason prompt	neutral "no" probe

309

St+	St-	Sc+	Sc-
We'd call the rabbit who eats the grass a 2nd order consumer of matter in the nitrogen cycle. The grass is the 1st order consumer. It is important to note that matter producers and energy producers are not always the same living things. On board: energy carbon nitrogen producer: grass, grass, bacteria 1st order consumer: rabbit, rabbit, grass 2nd order consumer: snake, snake, rabbit This is a very important point. You need to specify which cycle or flow of energy you are talking about when you label the living things producers, 1st order consumers, etc.	We'd call the rabbit who eats the grass a 2nd order consumer of matter in the nitrogen cycle. The grass is the 1st order consumer. On board: energy carbon nitrogen producer: grass, grass, bacteria 1st order consumer: rabbit, rabbit, grass 2nd order consumer: hawk, hawk, rabbit So you need to specify which cycle or flow of energy you are talking about when you label the living things producers, 1st order consumers, etc.		

St+	St-	Sc+	Sc-	Re
Let's turn now to a matter cycle where we don't really need to talk about producers. This is the water cycle.	In the water cycle, we don't really need to talk about producers.			
Here's a diagram of the water cycle. On board: water cycle  	On board: water cycle  			

St+	St-	Sc+	Sc-	Rc+	Rc-
It's easy to see how water is cycled through the environment from this picture. But let's see what role living things play in the cycle.	It's easy to see how water is cycled through the environment from this picture.				
		(Hi) How can living things like trees and animals be involved in the water cycle? 1. drink water, then pass it back to environment via breathing or urine, 2. this then evaporates back into the atmosphere or drains into rivers, lakes.	(Lo) Living things like plants and animals give off the water they drink by exhaling and urinating. So does this also evaporate back into the atmosphere? yes - or it may drain into rivers, lakes	praise "no" + reason prompt On board: respiration wastes	neutral "no" probe
		(Hi) Why aren't there any producers in the water cycle? because there's no need to change water into an organic compound that can be used for life activities	(Lo) Since there isn't any need for water to be changed into an organic compound to be useful for life activities, are there any producers in the water cycle? no	praise "no" + reason prompt	neutral "no" probe
So in the water cycle, there are just consumers of water who use it in its natural form. There are no producers.	So in the water cycle, there are just consumers of water who use it in its natural form.				

312

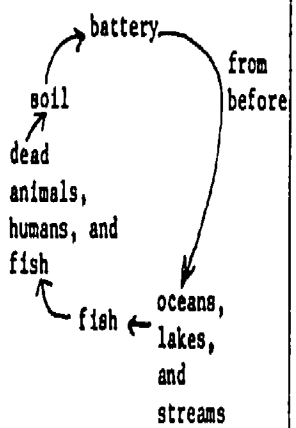
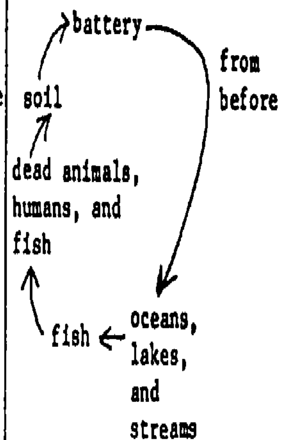
415

St+	St-	Sc+	Sc-	Rc+
Again, this points out the importance of being sure to mention the particular cycle you're talking about when you say the word "producer," or "consumer."				
OK - so far we've talked about cycles of matter that are good things for life. Let's look at a cycle of matter that's not good for life - the mercury cycle. On Board: mercury cycle	The carbon, nitrogen, and water cycles are good for life. The mercury cycle is not good for life.			

St+	St-	Sc+	Sc-	Re+	Re-
One place we find mercury is in dry cell batteries. After we throw away batteries whose power has been used up, they are often taken to a dump where they are burned. The mercury inside the battery becomes a vapor and is released into the atmosphere. It attaches itself to small dust particles much in the same way that water vapor does.	One place we find mercury is in dry cell batteries. After we throw away batteries whose power has been used up, they are often taken to a dump where they are burned. The mercury inside the battery becomes a vapor and is released into the atmosphere. It attaches itself to small dust particles much in the same way that water vapor does.				
		(Hi) Where do you think the mercury will go? into lakes and rivers with the rain since it dissolves in water	(Hi) The mercury vapor dissolves in water and falls to earth in the rain. So where will most of the mercury end up? in lakes and rivers	praise "no" + reason prompt	neutral "no" probe
Let's summarize what's happened so far in a diagram: On board: battery → dump → burning → mercury vapor → rain → oceans, lakes, and rivers	On board: battery → dump → burning → mercury vapor → rain → oceans, lakes, and rivers				

St+	St-	Sc+	Sc-	Rc+	Re-
Small bacteria and animals in the lakes and oceans change the mercury in the water into a poison, mercuric oxide.	Small bacteria and animals in the lakes and oceans change the mercury in the water into a poison, mercuric oxide.				
		(Hi) How do you think humans could get mercury poisoning then? 1. fish eats small animals, bacteria 2. humans eat fish or other animals that have eaten the poisoned fish	(Lo) If fish eat these animals and bacteria with the mercury, where is the poison mercuric oxide now? in the fish	praise "no" + reason prompt	neutral "no" probe
			(Lo) And if humans eat these fish or other animals that have eaten them, where does the poison mercuric oxide go? into the humans	praise "no" + reason prompt	neutral "no" probe
Another possibility is that the fish might simply die. Whatever, the mercuric oxide in the fish, or in animals and humans who eat these fish, is returned to the soil as mercury after the living things die and are decomposed.	Another possibility is that the fish might simply die. Whatever, the mercuric oxide in the fish, or in animals and humans who eat these fish, is returned to the soil as mercury after the living things die and are decomposed.				

315

St+	St-	Sc+	Sc-	Rc+	Rc-
To return to our diagram, then, we can add these steps in the mercury cycle. On board: 	On Board: 				
Let's see who the producers, consumers, and decomposers are in the mercury cycle.		(Hi) What is the producer in this cycle? How? humans - by mining mercury	(Lo) Since humans mine and burn the mercury to make a vapor that is absorbed by living things, who are the producers in the mercury cycle? humans	praise "no" + reason prompt On board: humans= produc-ers	neutral "no" probe
		(Hi) Who are the consumers in the mercury cycle? Why? humans, fish, animals, and bacteria	(Lo) And since fish, animals, and humans get mercury from the human producers, who are the consumers in the mercury cycle? fish, animals, and humans	praise "no" + reason prompt On board: humans, fish, animals= consum-ers	neutral "no" probe

316

419

420

St+	St-	Sc+	Sc-	Re+	Re-
OK - and regular decomposers play the role of decomposers in the mercury cycle.	OK - and regular decomposers play the role of decomposers in the mercury cycle.				
Now we've talked about four different matter cycles - carbon, nitrogen, water, and mercury. Let's look at these again to see what they have in common and how they are different.					
		(Hi) What do all 4 of the matter cycles have in common? 1. matter is constantly in the process of being reused 2. there are always consumers in every matter cycle	(Lo) Does each cycle involve matter? yes (Lo) And does each cycle have consumers? yes	Praise "no" + reason prompt On board	neutral "no" probe
So it's important to remember that every matter cycle involves matter and has consumers.					

St+	St-	Sc+	Sc-	Rc+	Re-
		(Hi) What things are not common to all 4 matter cycles? 1. different processes by which the matter is cycled - e.g., water uses evaporation and rain; nitrogen involves changing to a compound 2. producers are different 3. there are no producers for the water cycle	(Lo) Is there a producer for all the cycles? no - no producer for water cycle	praise "no" + reason prompt	neutral "no" probe
			(Lo) Are the producers the same living things for the nitrogen, carbon, and mercury cycles? What are the producers? 1. no 2. carbon - plants nitrogen - nitrogen-fixing bacteria 3. mercury - humans	praise "no" + reason prompt On board	neutral "no" probe
So we can see that all matter cycles have two important things in common - they involve <u>matter</u> and they have <u>consumers</u>. They also differ in 2 important ways - what the producers are, and what processes change the matter in the cycle.					
So we have a general model for matter cycles that usually describes these cycles, but not always. On board: environment → producers → consumers → decomposers → environment	So we have a general model for matter cycles that usually describes these cycles, but not always. On board: environment → producers → consumers → decomposers → environment				

318

424

423

St+	St-	Sc+	Sc-	Re+
It's important to remember that the general models in the science of ecology, like this one, are not perfect. They are not always true, but they do fit most of the cases in ecology.				
OK - we've covered a lot of material today, so let us briefly review what was in this lesson: We talked about: 1. all things are made of matter 2. matter is recycled in the ecosystem all the time 3. four matter cycles a. carbon cycle b. nitrogen cycle c. water cycle d. mercury cycle 4. the "actors" in the matter cycle: a. producers b. consumers c. decomposers 5. general diagram of a matter cycle: environment decomposers producers consumers				

Lesson V. Matter and Energy: Putting it all Together

St+	St-	S[illegible]	Sc- [illegible]c+
Review of previous lesson: Yesterday we talked about, 1. all things are made of matter. 2. matter is recycled in the ecosystem all the time. 3. four matter cycles a. carbon cycle b. nitrogen cycle c. water cycle d. mercury cycle 4. the "actors" in the matter cycle a. producers b. consumers c. decomposers 5. general diagram of a matter cycle. environment ↘ producers ↙ consumers ↖ decomposers ↗ environment			

Lesson V. Matter and Energy: Putting it all Together

St+	St-	Sc+	Sc-	Rc+
The objectives of today's lesson are: 1. to briefly review the lessons on energy and matter. 2. to describe the uses of energy and matter for living things. 3. to show how energy and matter are interrelated. 4. to discuss how food chains and food webs are carriers of matter and energy.				
Before we begin our lesson, I would like to outline what we will be talking about today. (on board) 1. review of energy. a. types of energy b. producers and consumers of energy c. energy flow and heat loss d. energy pyramids e. conservation of energy				

St+	St-	Sc+	Sc-	R
2. review of matter. a. recycling b. producers, consumers, and decomposers c. matter cycles 3. uses of energy and matter. a. energy (1) "binding" matter (2) activity (3) storage b. matter (1) make body parts (2) "carrier" of energy (e) to perform "photo-synthesis" 4. relations of energy and matter. a. energy "binds" matter b. matter "carries" energy c. energy and matter for photo-synthesis 5. food chains and food webs				
428				

St+	St-	Sc+	Sc-	Re+	Re-
Now let's start talking about the material on energy.					
		(Lo) What are the two types of energy? potential, kinetic	(Lo) What are the two types of energy? potential, kinetic	Praise "no" + reason prompt on board	Neutral "no" probe
		(Lo) Who can tell me what these mean? potential = stored kinetic = active	(Lo) Who can tell me what these mean? potential = stored kinetic = active	Praise "no" + reason prompt on board	Neutral "no" probe
		(Lo) Can anyone give me examples of these two types of energy? potential = food kinetic = activity	(Lo) Can anyone give me examples of these two types of energy? potential = food kinetic = activity	Praise "no" + reason prompt ~~on board~~	Neutral "no" probe
Let's move on to producers and consumers					
		(Lo) What is a producer of energy? plants that can make their own food.	(Lo) What is a producer of energy? plants that can make their own food.	Praise "no" + reason prompt on board	Neutral "no" probe
		(Hi) Are all green plants producers? yes Are all plants producers? no, mushrooms, fungi, bacteria.	(Lo) Give me some examples of producers of energy.	Praise "no" + reason prompt on board	Neutral "no" probe

St+	St-	Sc+	Sc-	Rc+	Rc-
It is important to note that we are talking about producers <u>of</u> <u>energy</u>, in a little while we will talk about producers <u>of</u> <u>matter</u>.	Producers of energy are organisms (usually green plants) that can convert energy from sunlight into a form which is usable in the Ecosystem.				
Let's talk about energy consumers for a moment.					
		(Lo) Can anyone tell me what an energy consumer is? a living thing which cannot make its own energy. give me examples?	(Lo) Can anyone tell me what an energy consumer is? a living thing which cannot make its own energy. give me examples?	Praise "no" + reason prompt on board	Neutral "no" probe
Here again we are talking about consumers <u>of</u> <u>energy</u>, not consumers of matter. But they are usually the same organisms.	Consumers of energy are organisms that cannot make energy (food) for themselves and must rely on producers.				

St+	St-	Sc+	Sc-	Rc+	Re-
In the previous units we also talked about energy flow. I would like to review that now. We saw that energy was passed from producers to consumers	Energy flow is the movement of energy in the ecosystem. Energy is passed from the producers to the consumers.				
		(Lo) What did we say about <u>how</u> the energy moves in the ecosystem? unidirectionally	(Lo) What did we say about <u>how</u> the energy moves through the ecosystem? unidirectionally	Praise "no" + reason prompt on board	Neutral "no" probe
		(Lo) And why does it flow in one direction? heat loss (Hi) Where and when do we produce heat? during activity + metabolism in animals mostly (Lo) What is happening between the two types of energy? potential is being converted to kinetic which is activity and heat.	(Lo) Energy flows in one direction because of heat loss. Where does the heat loss occur? during activity in animals usually (Lo) Give me an example of energy flow and heat loss. fox runs (+ loses heat) to catch the rabbit for food (energy flow).	Praise "no" + reason prompt on board	Neutral "no" probe

325

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Lo) What does an energy pyramid show us? How much energy is lost from the sun to producers to consumers.	(Lo) Also during heat production the potential energy in the food is being changed into kinetic energy. What happens to the kinetic energy? 1. used in activity 2. lost as heat	Praise "no" + reason prompt on board	Neutral "no" probe
		(Lo) What do we mean when we talk about different orders of consumers, like 1st-order 2nd-order? there is a relationship and the higher eats a lower one. Give me an example of different orders of consumers.	(Lo) An energy pyramid shows the amount of energy lost as we move from sun to producers to consumers. (Lo) What animal(s) is at the top of the pyramid? humans, highest order consumers (Lo) Give me an example of a chain of relationships in the energy flow diagram that shows how there are higher orders of consumers. mouse → snake → hawk 1st 2nd 3rd	Praise "no" + reason prompt on board	Neutral "no" probe

326

St+	St-	Sc+	Sc-
Finally the lessons on energy talked about the conservation of energy. This means that the total of all the energy stored as potential energy and the energy lost as heat is always the same.	Energy comes into the ecosystem from the sun. The plants use some of it and the rest is passed along to the consumers, and some is lost as heat. This is called conservation of energy, because the total amount is always the same.		
Now I'd like to talk about the lesson on matter and matter cycles.			
You'll remember that matter was what everything was made out of.	Matter is a substance that everything is made out of.		

St+	St-	Sc+	Sc-	Rc+	Rc-
		Give me some examples of matter.	Give me some examples of matter.	Praise "no" + reason prompt	Neutral "no" probe
		(Hi) What is the difference between matter cycles and energy flow? matter complete cycle energy = unidirectional What are the four matter cycles we discussed? carbon, nitrogen, water, mercury	(Lo) We said that matter always recycles around in the ecosystem. What were the four kinds of matter cycles we talked about? carbon, nitrogen, water, mercury	Praise "no" + reason prompt on board	Neutral "no" probe
		(Lo) Who are the actors in the matter cycles? producers, consumers, decomposers (Hi) What are the relationships between the actors in the matter cycle? 1. producers use matter from non-living world. 2. consumers get matter from producers. 3. decomposers break down living things and return the matter to the non-living world.	(Lo) What are the three kinds of actors in the matter cycle? producer, consumer, decomposer And we said that producers use matter directly from the non-living environment, the consumers get matter from the producers and the decomposers break down the living things and return the matter to the non-living world.	Praise "no" + reason prompt on board	Neutral "no" probe

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Hi) What is the difference between a producer of energy and a producer of matter? energy producer = able to make food + energy from the sun. matter producer = able to use matter from non-living world. What is similar about these producers? 1. they are usually both green plants. 2. they both use materials (sunlight + matter) directly from the non-living world.	(Lo) Producers of energy and producers of matter are different. What is a producer of energy? able to use energy from the sun. What is a producer of matter? able to use matter directly from non-living world. The difference is that one produces energy and the other "produces" matter for other living things to use.	Praise "no" + reason prompt	Neutral "no" probe
		(Hi) Give me an example of a matter producer that is <u>not</u> a green plant. 1. the bacteria that live in root bundles that are the producers in the nitrogen cycle. 2. humans produce mercury for the mercury cycle.	(Lo) Give me some examples of energy and matter producers energy - green plants matter - nitrogen ⟶ fixing bacteria humans ⟶ mercury green plants ⟶ carbon	Praise "no" + reason prompt	Neutral "no" probe

St+	St-	Sc+	Sc-
So now we have seen the difference between energy producers and matter producers. These two types of producers are usually the same, but in some matter cycles the producers are not green plants. We must realize that these are general definitions and sometimes we can think of examples that don't fit, but in this lesson we are not concerned with the exceptions.	These definitions of energy producers and matter producers are general definitions, and we can probably think of examples that don't fit. The science of ecology is concerned with general principles and in this lesson we will not be concerned with the exceptions.		
Now let's move on to the last topic: The matter cycles.			

St+	St-	Sc+	Sc-	Re+	Re-
		(Lo) Can someone describe a general model of the matter cycle? non-living world environment ↑ ↓ decomposers producers ↖ ↙ consumers	(Lo) Draw: environment ↑ ↓ decomposers producers ↖ ↙ consumers We had a special name for this relationship, what was it? the general model of the matter cycle	Praise "no" + reason prompt on board	Neutral "no" probe
There was one more thing I would like to make clear. Let's talk about it now.					
		(Lo) Name some decomposers and tell me what their function is. they break down formerly living things to return the matter to the non-living world. e.g., fungi, molds, bacteria	(Lo) In matter cycles we have a group of organisms called decomposers. What do they do? break down formerly living things to return matter to the non-living world. What kinds of organisms are decomposers? fungi, molds, bacteria	Praise "no" + reason prompt on board	Neutral "no" probe

331

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Lo) Where do decomposers fit in the energy flow diagrams? they are considered the highest-order consumer of energy.	(Lo) Where do decomposers fit into the energy flow diagram? they are considered the highest-order consumer of energy.	Praise "no" + reason prompt	Neutral "no" probe
Now that we are done reviewing the lessons on energy and matter, I would like to move on and talk about the users of matter and energy. Let's start out with matter.					
We said that all things were made of matter.	All things are made of matter.				

332

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Hi) How do living things use matter? (give only one answer) a. make body parts b. "carrier" of energy c. required for photosynthesis.	(Hi) How do living things use matter? (give only one answer) a. make body parts b. "carrier" of energy c. required for photosynthesis.	Praise "no" + reason prompt on board	Neutral "no" probe
One of the uses of matter is to build body parts. All living things are made of matter; the bones, skin, organs, etc., all consist of matter. So one use of matter is to build body parts.	Living things use matter to build body parts. Bones, skin, organs, and everything in the body is made of matter. Plants use matter to build leaves, stems, and roots. One use of matter is to build body parts.				
		(Hi) How is matter used in photosynthesis? need CO_2, water, and chlorophyll to make photosynthetic machinery run. How does the plant get these things? through roots and leaves	(Lo) Photosynthesis requires sunlight, carbon dioxide, water, and chlorophyll. Which of these things are matter? CO_2, water, chlorophyll (Hi) How does the plant get these things? by absorbing them in the roots and through the leaves	Praise "no" + reason prompt	Neutral "no" probe

St+	St-	Sc+	Sc-	Re+	Re-
		(Hi) Why does the plant need sunlight for photosynthesis? to bind the carbon atoms together to make sugar, which is used as food by the plant and animals.	(Lo) Plants need sunlight to bind the carbon atoms together to make sugar. What is another name for sunlight? energy	Praise "no" + reason prompt	Neutral "no" probe
		(Lo) What kind of energy is in the sugar that the plant makes? potential	(Lo) When the plant makes sugar, it is converting the energy in sunlight to what type of energy? potential	Praise "no" + reason prompt on board	Neutral "no" probe
		(Lo) Where is the potential energy stored? in matter	(Lo) In what substance is the potential energy stored? matter	Praise "no" + reason prompt on board	Neutral "no" probe
This is important: The plant uses sunlight to make sugar out of carbon atoms. The sugar is potential energy. The potential energy is stored in matter. Energy and matter are both necessary for photosynthesis.	The plant uses sunlight to make sugar by binding carbon atoms together. Carbon is matter, and sunlight is energy. Matter and energy are both necessary for the plant to make food.				

334

St+	St-	Sc+	Sc-
Now we see one way that energy and matter are interrelated.	Matter and energy are related in photosynthesis.		
Let's summarize what we said about the uses of matter. First of all we said matter was used to make body parts. Secondly, we said that matter is required for photosynthesis. Thirdly, we found out that matter acts as a "carrier" of energy. Potential energy is stored inside of matter. How it is stored is very complicated and we will not talk about that.	Matter is used in photosynthesis, in building body parts and it acts as a carrier of potential energy.		

St+	St-	So+	So-	Re+	Re-
Now let's talk about the uses of energy in living things.					
		(Lo) Where does all the earth's energy come from originally? the sun	(Lo) Where does all of our energy on earth come from? the sun	Praise "no" + reason prompt on board	Neutral "no" probe
		(Lo) Matter builds body parts; what "binds" the matter together? energy	(Lo) We said that matter is used to build body parts, but what "binds" the matter together? energy	Praise "no" + reason prompt on board	Neutral "no" probe
So one use of energy is for binding body parts together. (on board)					
		(Lo) What is another use of energy, that mostly animals use? to make them active and move around	(Lo) Can you tell me one thing that the animals use energy for? to run around and be active	Praise "no" + reason prompt on board	Neutral "no" probe

336

452

453

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Hi) Why do animals want to be active and move around? so they can find food, reproduce, etc. (Lo) What kind of energy is in food? potential (Lo) What happens to the potential energy when the animals run around? 1. converted to kinetic 2. kinetic energy is used and converted to unusable heat.	(Lo) Why do animals use energy to move around? so they can go out and find food. (Hi) What is happening to the potential energy that is stored in the food when the animal runs around? 1. it is con .ced to kinetic energy. 2. kinetic energy is used and converted into heat which is unusable.	Praise "no" + reason prompt on board	Neutral "no" probe
So the second use of energy is to make organisms active so they can find food. Plants use energy to make chlorophyll so they can make more food (energy) in photosynthesis.	Plants use energy to make things like chlorophyll, which is required for them to make food in photo-synthesis.				

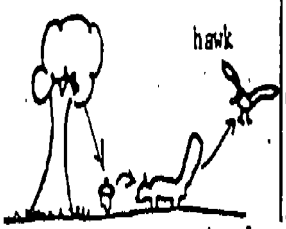
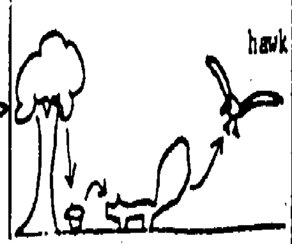
337

St+	St-	Sc+	Sc-	Re+	Re-
Now we will talk about a third use of energy in living things.					
During the times of year when food is very plentiful, many animals eat a lot and add a lot of fat to their bodies.	During the times of year when food is very plentiful, many animals eat a lot and add a lot of fat to their bodies.				
		(Hi) What do you suppose is stored in this fat? potential energy	(Lo) What kind of energy is stored in fat? potential	Praise "no" + reason prompt	Neutral "no" probe
		(Lo) So what is the third use of energy in living things? potential energy is stored so it can be used later when the organism needs it.	(Lo) Why is energy stored in fat? so the organism can use it when it needs it, like during cold winters or when food runs out.	Praise "no" + reason prompt	Neutral "no" probe

338

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Lo) Why would an organism want to store fat in its body? so it can have it when it needs it, like in the winter, or when there is a lack of food.	The storage of energy for later use is the third use of energy.	Praise "no" + reason prompt	Neutral "no" probe
To summarize, the three uses of energy are: 1. to "bind" matter together to build body parts. 2. to make organisms active. 3. to be stored for later use.					
Now let's go on to discuss how energy and matter are related in an example.					

339

St+	St-	Sc+	Sc-	Rc+	Rc-
I would like to use the example of a simple food chain. The chain involves the tree ⟶ acorn ⟶ squirrel ⟶ hawk. Draw: tree hawk  acorn squirrel	An example of how matter and energy are related can be seen in the ~~tree~~ tree ⟶ acorn ⟶ squirrel ⟶ hawk food chain. Draw: tree hawk  acorn squirrel				
In this example we will look at energy flow and a part of a matter cycle.					
		(Lo) What is a food chain? a pathway that allows energy and matter to move from individual to individual in the eco-system.	(Lo) What is a food chain? a pathway that allows energy and matter to move from individual to individual in the eco-system.	Praise "no" + reason prompt	Neutral "no" probe

340

461

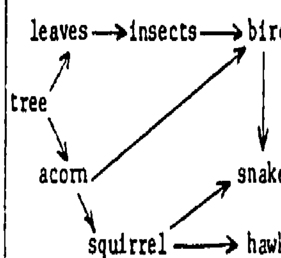
St+	St-	Sc+	Sc-	Re+	Re-
		(Lo) Which is the energy producer? the tree	(Lo) Which is the energy producer? the tree	Praise "no" + reason prompt on board	Neutral "no" probe
		(Lo) Which is the matter producer? the tree	(Lo) Which is the matter producer? the tree	Praise "no" + reason prompt on board	Neutral "no" probe
The energy producer and the matter producer are the same in this food chain. We also know that the tree makes energy by photosynthesis, when the sunlight strikes the leaves and when carbon dioxide, water, and chlorophyll are present. The tree stores the energy in simple sugar which is eventually incorporated into the acorn. So the acorn contains potential energy and carbon matter.	The tree makes sugar by photosynthesis. The sugar is stored in the leaves, stem, roots, and even in the acorn. The acorn contains energy and carbon matter.				

St+	St-	Sc+	Sc-		Re-
		(Hi) When the squirrel comes along and eats the acorn, what happens to the energy and carbon matter? the energy is now in the squirrel and he can use it to be active, or "bind" the carbon from the acorns to make bones, etc., or he can store it as fat.	(Hi) When the squirrel comes along and eats the acorn, what happens to the energy and carbon matter? the energy is now in the squirrel and he can use it to be active, or "bind" the carbon from the acorns to make bones etc., or he can store it as fat.	Pro "no" rea [illegible]	Neutral "no" probe
So now the energy from the sun that the tree has stored in the acorn is now in the squirrel. The carbon that was in the acorn is also in the squirrel.	The energy and carbon matter that were in the acorn are now in the squirrel.				

St+	St-	Sc+	Sc-	Rc+	Re-
		(Hi) Who can tell me what happens to the energy when the hawk eats the squirrel? the energy would be passed to the hawk and he would use it to: 1. "bind" matter together to build body parts. 2. store it as fat.	(Lo) Suppose the hawk ate the squirrel and the energy was passed to the hawk. What would the hawk use the energy for? 1. "bind" matter together to build body parts. 2. store it as fat.	Praise "no" + reason prompt on board	Neutral "no" probe
		(Hi) What would happen to the carbon matter that was in the squirrel? 1. get passed to the hawk. 2. hawk uses it to build body parts. 3. the matter acted as the carrier of energy to the hawk.	(Lo) The hawk ate the squirrel and passed the carbon matter to the squirrel. The matter acted as the "carrier" of the energy in this transfer. What else could the hawk use the matter for? to build body parts	Praise "no" + reason prompt on board	Neutral "no" probe

343

St+	St-	Sc+	Sc-	R
In summary we saw that the energy was stored in sugar by photosynthesis in the tree. At the same time the carbon acted as the "carrier" of the energy, and carbon was also stored in the acorn. The squirrel ate the acorn and used the energy, the squirrel also used the carbon matter in the acorn. When the hawk ate the squirrel the energy and matter were passed to the hawk. This whole chain is called a food chain. The "food" was both energy and carbon matter.	This is an example of a food chain, where the food consisted of energy <u>and</u> carbon matter that was passed from tree → acorn → squirrel → hawk.			

St+	St-	Sc+	Sc-	Rc+	Rc-
Now let's talk about the final topic of this lesson. That topic is food webs.					
A food web is a combination of food chains.	A food web is a combination of food chains.				
		(Lo) What is an example of a food web? any group of relations where more than one organism acts as food for another.	An example is: 	Praise "no" + reason prompt on board	Neutral "no" probe

St+	St-	Sc+	Sc-
Review of this lesson. I. Review of energy lessons. A. types of energy B. producers and consumers of energy C. energy flow D. conservation of energy II Review of matter lesson. A. recycling B. producers, consumers, and decomposers of matter C. matter cycles III. Uses of matter and energy A. matter 1. make body parts 2. "carrier" of energy 3. to perform photosyntheses B. energy 1. "binding" matter 2. activity 3. storage IV. Relations of matter and energy A. energy "binds" matter B. matter is "carrier" of energy C. both required for photosynthesis V. Food chains and food webs.			

St+	St-	Sc+	Sc-
Before we start today's lesson, let's briefly review what we covered yesterday.			
1. review of lessons on energy: a. types of energy b. producers and consumers in energy flow c. conservation of energy 2. review of lessons on matter: a. cycles - idea of b. producers, consumers, and decomposers in matter cycles 3. uses of matter and energy: a. body parts b. carrier of potential energy c. photosynthesis d. bind matter e. activity 4. food chains and food webs as pathways for energy			
OK - that covers yesterday			

St+	St-	Sc+	Sc-	
We've got several major goals for today's lesson. They are: 1. learn definition of population, - be able to give examples of populations - be able to use the term "populations" to talk about ecosystems other than the one you read about 2. know the factors that increase and decrease size of populations. - be able to use these factors to describe what happens to certain populations - able to understand and read a growth curve - be able to use a growth curve to show what happens to a population.				

St+	St-	Sc+	Sc-
Now let me give you a short outline to help you review what you read and also to let you know what we will be talking about today. Content outline: 1. populations 2. things that affect the size of populations a. causes increase; (1) birth rate (2) migration into b. causes decrease; (1) death rate (2) migration out 3. picture of population growth - "growth curve".	Today we're going to talk about populations.		

St+	St-	Sc+	Sc-	Rc+	Re-
Now that I've told you briefly what we will be talking about today, let's get started talking about what a population is.		(Lo) Can anyone give me a definition of a population? group of one kind of living thing living in same geographic area	(Lo) Can anyone give me a definition of a population? group of one kind of living thing living in same geographic area	praise "no" + reason prompt On board	neutral "no" probe
		(Lo) Who can give me an example of a population in the foothills? (from text) ground squirrels, field sparrows, blueberry bushes, black ants, bacteria, red ants, and field mice	(Lo) Who can give me an example of a population in the foothills? (from text) ground squirrels, field sparrows, blueberry bushes, black ants, bacteria, red ants, and field mice	praise "no" + reason prompt On board	neutral "no" probe

350

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Lo) Why is (isn't) that an example of a population? group of one specific kind of living thing living in same geographic area	(Lo) Why is (isn't) that an example of a population? group of one specific kind of living thing living in same geographic area	praise "no" + reason prompt On board	neutral "no" probe
		(Lo) Who can give me another example of a population in the foothills? any answer that fits definition (i.e., one kind and lives in same geographic area) or is from the text.	(Lo) Who can give me another example of a population in the foothills? any answer that fits definition (i.e., one kind and lives in same geographic area) or is from the text.	praise "no" + reason prompt On board	neutral "no" probe
		(Lo) Why is (isn't) that an example of a population? group of one specific kind of living thing living in same geographic area.	(Lo) Why is (isn't) that an example of a population? group of one specific kind of living thing living in same geographic area.	praise "no" + reason prompt On board	neutral "no" probe

351

St+	St-	Sc+	Sc-	Rc+	Re-
		(Hi) Can we use the term "population" to describe groups of similar plants as well as groups of similar animals? Why or why not? yes, because both plants and animals are living things, and our definition says that a population is one kind of living thing which could mean either plant or animal.	(Lo) According to your reading and what we've said so far, do ecologists use the term "population" to describe groups of similar plants as well as groups of similar animals? yes	praise "no" + reason prompt On board	neutral "no" probe
Let's summarize the important things we've said so far: First, a population is a group of one kind of living thing that lives in one geographic area. Second, we've come up with several examples of populations in the foothills: ____, ____, ____. We decided that these are examples of populations because they are one kind of living thing living in the same geographic area. Finally, we saw that populations can be made up of either similar kinds of animals or similar kinds of plants.					

352

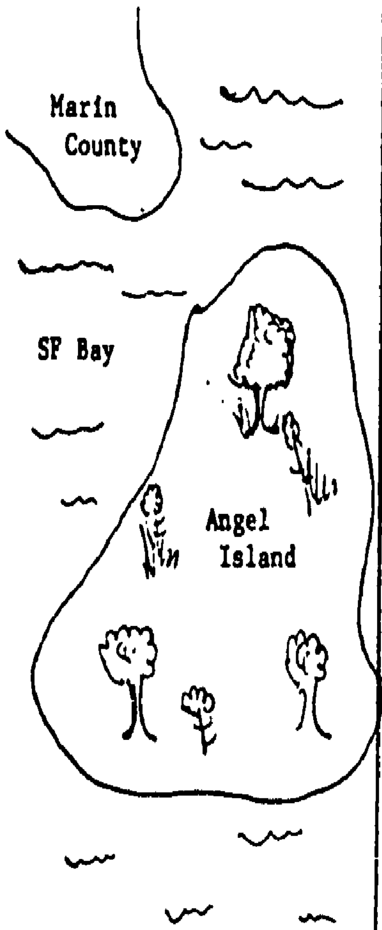
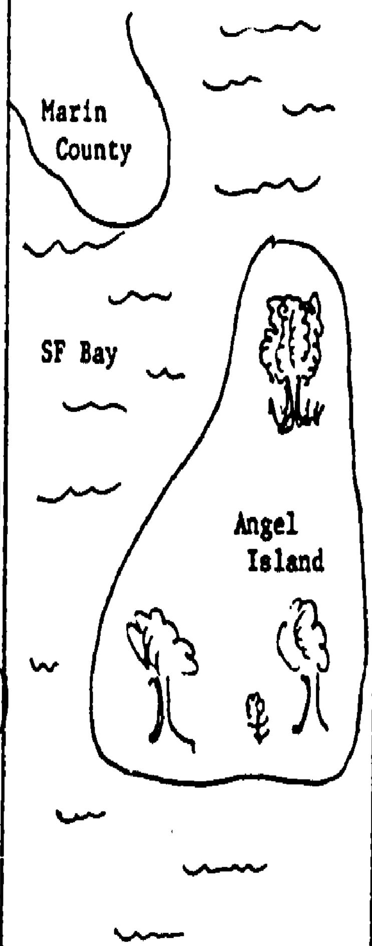
St+	St-	Sc+	Sc-	Rc+	Re-
		(Hi) Why do you think ecologists talk about populations rather than about the individual plants or animals? because it is easier to find general laws about populations than to find laws to describe an individual living thing. For example, the ecologist has developed ways of telling what will happen to the size of a population. He knows what factors affect the size of a population. But it is much more difficult to try to tell what will happen to a particular individual plant or animal--whether it will live or die.	Ecologists talk about populations rather than individual plants or animals because it is easier to find general laws about populations than to find laws to describe an individual living thing. For example, the ecologist has developed ways of predicting or telling what will happen to the size of a population. He knows what factors affect the size of a population. But it is much more difficult to try to tell what will happen to a particular plant or animal--whether it will live or die.	praise "no" + reason prompt On board	neutral "no" probe

353

St+	St-	Sc+	Sc-	Re+	Re-
			(Lo) Why do ecologists talk about populations rather than about the individual plants or animals in the population? because ecologists can find general laws which describe populations	Praise "no" + reason prompt On board	Neutral "no" probe
Now let's talk about those general laws that ecologists have discovered that affect the size of populations. Remember from your reading that there are certain things that increase the size of populations and there are other things that decrease the size of populations. We are going to talk about these general laws using the populations of plants and animals that live on Angel Island, to illustrate the causes of population increase and decrease.					

354

St+	St-	Sc+	Sc-
How many of you have been to Angel Island? (Allow students to respond by raising hands)	How many of you have been to Angel Island? (Allow students to respond by raising hands)		
Let me begin by telling you a little bit about Angel Island as a review for those of you who have been there and as background for those of you that haven't been there:			
Angel Island is an island in the middle of San Francisco Bay. Thousands of years ago it was a peninsula, but now it is separated from Marin County by water so the only way to get to the island is by boat. On the island there are lots of plants and animals that are also found in Marin County, and there are some things that are unique to the island because they were introduced by humans.	Angel Island is an island in the middle of San Francisco Bay. Thousands of years ago it was a peninsula, but now it is separated from Marin County by water so the only way to get to the island is by boat. On the island there are lots of plants and animals that are also found in Marin County, and there are some things that are unique to the island because they were introduced by humans.		

<table>
<tr><th>St+</th><th>St-</th><th>Sc+</th></tr>
<tr><td>(Draw on board)
</td><td>(Draw on board)
</td><td></td></tr>
<tr><td>So here's our map of Angel Island. As you can see, there are lots of trees and flowers on Angel Island</td><td>There are lots of trees and flowers on Angel Island</td><td></td></tr>
</table>

St+	St-	Sc+	Sc-	Re+	Re-
		(Hi) Would all the trees on Angel Island be considered a population? Why or why not? No, because although the trees do live in a limited geographic area, there are many different kinds of trees.	(Lo) There are many different kinds of trees on Angel Island like Eucalyptus, Oak, Bay, Madrone, and Pine. Would all the trees on Angel Island be considered a population? no	praise "no" + reason prompt On board	neutral "no" probe
		(Hi) What is an example of a kind of tree on Angel Island that would be considered a population? eucalyptus, oak, bay, madrone, pine.	(Lo) Would all the eucalyptus trees on Angel Island be considered a population? yes	praise "no" + reason prompt On board	neutral "no" probe
Let's go on to think about animals on Angel Island. On the island there are some small animals like chipmunks and squirrels. However, the only large animal on the island is the Columbian black-tailed deer. It is estimated that there are about 100 Columbian black-tailed deer on the island.	On the island there are some small animals like chipmunks and squirrels. However, the only large animal on the island is the Columbia black-tailed deer. It is estimated that there are about 100 Columbian black-tailed deer on the island.				

357

St+	St-	Sc+	Sc-	Rc+	Rc-
(Add a picture of a deer to the drawing)	(Add a picture of a deer to the drawing)				
		(Hi) Would all the Columbian black-tailed deer on Angel Island be considered a population? Why or why not? yes, because they live in the same geographic area, and they are a particular kind of deer.	(Hi) Would all the Columbian black-tailed deer on Angel Island be considered a population? Why or why not? yes, because they live in the same geographic area, and they are a particular kind of deer.	Praise "no" + reason prompt on board	Neutral "no" probe
In the text you read about some things that affect populations. Using the deer as an example, we're now going to talk about the things that cause the size of populations to increase or decrease.					
		(Hi) How do you think the deer got to Angel Island in the first place? deer migrated in from mainland by swimming	(Lo) What are the things that you read about which increase the size of a population? migration birth rate	Praise "no" + reason prompt on board	Neutral "no" probe

358

439

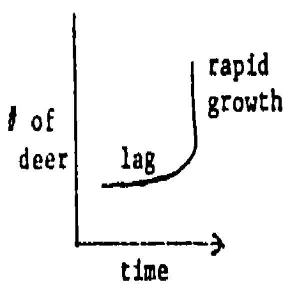
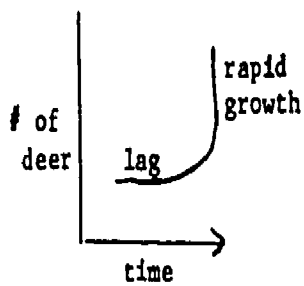
400

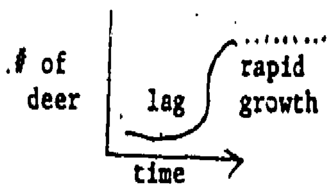
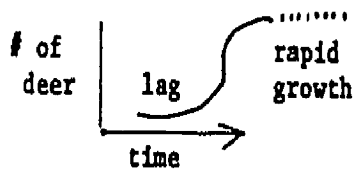
St+	St-	Sc+	Sc-	Re+	Re-
		(Hi) Once the deer got to Angel Island, what would have caused the size of their population to increase? birth rate	The deer first came to Angel Island by migrating in. Once the deer got to the island, the size of their population increased due to reproduction.	praise "no" + reason prompt On board	neutral "no" probe
Let's summarize: We've mentioned the two things that increase populations: 1. migration in 2. birth rate					
		By the early 1900's (Hi) there were no longer any deer on Angel Island. What do you think could have happened to them? starvation predation migration out (this is unlikely unless there wasn't enough food so they swam back to the mainland)	What are the three (Lo) things you read about that decrease the size of the population? starvation predation (killed by other animals) migration out By the early 1900's, there were no longer any deer on Angel Island.	praise "no" + reason prompt On board	neutral "no" probe

St+	St-	Sc+	Sc-	Re+	Re-
		(Hi) Most of the deer probably died because of starvation or were killed by predators. Since there are no natural predators of deer on the island, who do you think might have killed off the deer? Hunters who came by canoe from the mainland	Most of the deer probably died because of starvation or were killed by predators. Since there are no natural predators of deer on the island, many of the deer might have been killed off by hunters.	praise "no" + reason prompt On board	neutral "no" probe
Let's summarize the causes of population decrease: 1. limited food supply (starvation) 2. predation 3. migration out					
Sixty years ago the deer were all gone. Then the U.S. Army took over Angel Island, and they decided that it would be nice to have some deer on the island so they brought in several pair of Columbian black-tailed deer.	Sixty years ago the deer were all gone. Then the U.S. Army took over Angel Island, and they decided that it would be nice to have some deer on the island so they brought in several pair of Columbian black-tailed deer.				

360

493 494

St+	St-	Sc+	Sc-
Now I'm going to draw you a picture to show how the size of the deer population has grown since the Army brought a few deer to the island. We call this picture a "growth curve."			
(Draw on board)  This is a picture of how the size of the deer population has grown since the Army brought them to Angel Island sixty years ago. (Explain that # of deer is plotted against time in a way students can understand) We call this picture a "<u>growth</u> <u>curve</u>."	(Draw on board)  This is a picture of how the size of the deer population has grown since the Army brought them to Angel Island sixty years ago. (Explain that # of deer is plotted against time in a way students can understand) We call this picture a "growth curve."		

<table>
<tr><th>St+</th><th>St-</th><th>Sc+</th></tr>
<tr><td>It is <u>important</u> to notice that when the population is first getting started, we call it the "<u>lag</u>" part of the curve. When the population gets going, it grows very fast and we call it "<u>rapid growth</u>."</td><td></td><td></td></tr>
<tr><td>Under normal circumstances, the things increasing a population will be balanced out by the things decreasing a population so that finally the population will stay the same size. We can show this by adding a dotted line to our grown curve:

</td><td>Under normal circumstances, the things increasing a population will be balanced out by the things decreasing a population so that finally the population will stay the same size.
We can show this by adding a dotted line to our growth curve:

</td><td></td></tr>
</table>

St+	St-	Sc+	Sc-	Rc+	Rc-
			(Erase words "lag" and "rapid growth") (Lo) Which part of the curve shows when the population is just getting started? the lower part or lag phase	praise "no" + reason prompt On board	neutral "no" probe
			(Lo) Which part of the curve shows when the population is fast-growing? the steep part or rapid growth	praise "no" + reason prompt On board	neutral "no" probe
			(Lo) Which part of the curve shows when the population is staying the same? the flat plateau shown by the dotted line	praise "no" + reason prompt On board	neutral "no" probe
Let's consider the deer population on Angel Island to see whether the things increasing the population are being balanced out by decreases.					

363

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Hi) What is now increasing the deer population on Angel Island? birth rate	The deer population on Angel Island is increasing due to reproduction. Every doe usually has twins every year.	praise "no" + reason prompt On board	neutral "no" probe
		(Hi) Can you think of two factors about birth rate that increase the size of a population? number in litter amount of time between births	(Lo) If half of the 100 deer on Angel Island are female, the deer population would be increased by how many deer per year? 100	praise "no" + reason prompt On board	neutral "no" probe
		(Hi) On Angel Island what would you have to know to figure out how many new deer would be born each year? number of does number of babies that each doe has number of times a doe gives birth per year	(Lo) What are the two things that are involved in this increase of birth rate? each doe has twins (or size of litter) each doe gives birth every year	praise "no" + reason prompt On board	neutral "no" probe

364

500

499

St+	St-	Sc+	Sc-	Rc+	Re-
OK, so we know that the deer population on Angel Island is increasing due to reproduction. Now let's talk about whether the deer population on Angel Island is decreasing at all.					
		(Hi) Are there any factors which are significantly decreasing the deer population on Angel Island? Why? no probably not migration out because deer would not swim off no predation because no natural predators on the island, and it is a state park so hunting is prohibited not starvation until island becomes overpopulated probably only a few natural deaths	(Lo) From your reading what things could decrease the population of deer on Angel Island? migration out predation starvation Although these things <u>could</u> decrease the deer population, they probably are not. No migration out because deer would have to swim. No predation because no natural animal predators, and it is a state park so hunting is prohibited. No starvation until island becomes overpopulated.	Praise "no" + reason prompt On board	Neutral "no" probe

365

St+	St-	Sc+	Sc-	Rc+	Re-
		(Hi) Where would the deer population be on the growth curve then? still in period of rapid growth	(Lo) Is the deer population on Angel Island decreasing? no	praise "no" + reason prompt On board	neutral "no" probe
			(Lo) If the deer population is growing and not decreasing, where would the deer population be on the growth curve? still in period of rapid growth	praise "no" + reason prompt On board	neutral "no" Probe
		(Hi) What will happen eventually to keep the population the same or stable as shown by the dotted line? island will become overpopulated with deer, and they will starve to death.	Eventually the island will become overpopulated with deer, and the population will decrease because many deer will starve to death. We could show this decrease in population with a downward curve after the plateau (draw on board).	praise "no" + reason prompt On board	neutral "no" probe
		(Hi) How could we show this overpopulation and starvation on the curve? downward curve after the plateau (draw on board)		praise "no" + reason prompt On board	neutral "no" probe

366

503 504

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Hi) What could humans do to decrease the deer population on Angel Island before it becomes too large and many deer starve to death? predation: (1) allow hunters to come in (2) introduce natural animal predators man-made migration out--catch deer and convey them elsewhere	(Hi) What could humans do to decrease the deer population on Angel Island before it becomes too large, and many deer starve to death? predation: (1) allow hunters to come in (2) introduce natural animal predators man-made migration out--catch deer and convey them elsewhere	praise "no" + reason prompt On board	neutral "no" probe
		(Hi) Why do you think each of the above alternatives is unsatisfactory? (1) allowing hunters to kill them makes it more of a massacre than a sport because deer are so tame (2) can't introduce natural predators like cougar because of human visitors to the park (3) no one else wants deer so can't take them elsewhere (4) maybe man should not interfere with nature		praise "no" + reason prompt On board	neutral "no" probe

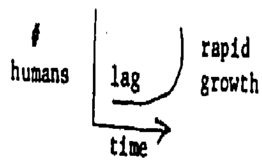
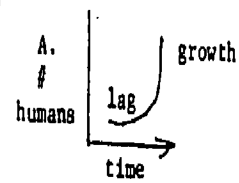
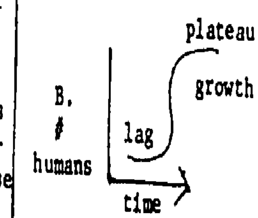
367

St+	St-	Sc+	Sc-	Rc+	Re-
For the final part of the lesson, let's take the idea of balancing out increases and decreases in populations and apply it to human populations.					
		(Lo) What are some differences between humans and animals that affect the size of human populations? humans have invented medicine which decreases deaths of babies and increases life span. humans have no natural predators except other humans (i.e., war) birth control methods	(Lo) Does the same idea of balance between things that increase and decrease the size of populations apply to humans? yes, with some differences	praise "no" + reason prompt On board	neutral "no" probe
			(Lo) What are some differences between human populations and animal populations? humans have invented medicine which decreases deaths of babies and increases life span. humans have no natural predators except other humans (i.e., war) birth control methods	praise "no" + reason prompt On board	neutral "no" probe

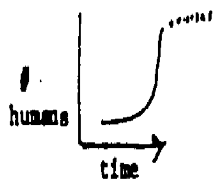
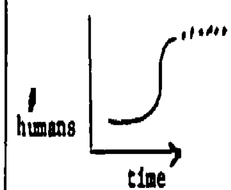
368

St+	St-	Sc+	Sc-	Rc+	Re-
		(Lo) Which of these differences between human and animal populations would cause the size of the human population to <u>increase</u>? Why? humans have invented medicine so fewer babies die and people live longer humans have no natural predators so are not killed naturally	(Lo) Which of these differences between human and animal populations would cause the size of the human population to <u>increase</u>? humans have invented medicine humans have no natural predators	praise "no" + reason prompt On board	neutral "no" probe
		(Lo) Which of the differences between human and animal populations would cause the size of the human population to <u>decrease</u>? Why? use of birth control methods because fewer babies would be born to replace the people that die of natural causes	(Lo) Which of the differences between human and animal populations would cause the size of the human population to <u>decrease</u>? use of birth control methods	praise "no" + reason prompt On board	neutral "no" probe

369

St+	St-	Sc+	Sc-	Rc+	Re-
		(Hi) What are two factors which decrease animal populations which might also decrease human populations? limited food supply or starvation migration out	What did your reading show was the one other control over human populations? starvation or amount of food available	praise "no" + reason prompt On board	neutral "no" probe
		(Hi) If we drew a picture or growth curve of the human population over the last 10,000 years, what would it look like? Why?  It took a while for size of population to get started (in lag phase) but population has grown rapidly since then due to increases in technology such as medicine to do away with disease that used to kill huge numbers of people.	(Lo) A graph can be used to show the growth of the human population over the last 10,000 years. Which of the graphs below would it look like? A.  B. 	praise "no" + reason prompt On board	neutral "no" probe

370

St+	St-	Sc+	Sc-	Re+	Re-
		(Hi) What would ecologists predict the graph would look like for the next hundred years? Why?  Size of population would remain the same or balance out due to overpopulation and limited food supply or because humans started using birth control methods to prevent overpopulation and starvation.	(Hi) What would ecologists predict the graph would look like for the next hundred years? Why?  Size of population would remain the same or balance out because of overpopulation and limited food supply or because humans started using birth control methods to prevent overpopulation and starvation.	praise "no" + reason prompt On board	neutral "no" probe

371

St+	St-	Sc+	Sc-
Let's now review the important concepts we talked about in today's lesson: 1. Population--definition; a. one kind of living thing b. living in limited geographic area 2. Things increasing size of populations a. birth rate (litter size and amount of time between births) b. migration in 3. Things decreasing size of population; a. starvation because of limited food supply b. killed off by predators c. migration out 4. Balance is usually created by things increasing and decreasing 5. "Growth curve"--picture of changes in size of population over time. 6. Things that increase size of human population; a. birth rate b. medicine (fewer babies die and people live longer) (Cont'd)			

Lesson VI. Populations

St+	St-	Sc+	Sc-
(Cont'd) 7. Things that decrease size of human population; a. birth control b. starvation That's all for today.	That's all for today.		

St+	St-	
Let me start today's lesson with a brief review of what we covered yesterday when we read and talked about populations. 1. Populations - definition (one species of living thing inhabitating same general geographic area. 2. Things increasing population size; a. birth rate b. migration in 3. Things decreasing population size; a. starvation b. predation c. migration out 4. Population balance. 5. Growth curve. 6. Things affecting size of human population; a. increases (1) birth rate (2) medicine b. decreases (1) birth control (2) starvation (3) migration out		

Lesson VII. Communities

St+	St-	Sc+	Sc-
Our objectives for today's lesson are: 1. See how populations interact and adapt in communities. 2. Look at some of the communities in the foothills area. 3. Discuss how communities change. OK - now that we know what our objectives for today are, I'll outline the material we'll cover, then get into it. Community. The dependence of several different populations all living in the same general area.			

St+	St-	Sc+
(On Board) Community Habitat — populations, plants, animals Factors changing communities — climate, Other natural factors		
Now that we've gone over our objectives and the outline of the lesson, let's get into the lesson by my asking you about some basic pieces of information	Today we read about communities.	
		What is the defi community that w reading? the dependenc several diffe populations a living in the general area

375

St-	Sc+	Sc-	Rc+	Re-
Today we read about communities.				
	(Lo) What is the definition of community that was in the reading? the dependence of several different populations all living in the same general area	(Lo) What is the definition of community that was in the reading? the dependence of several different populations all living in the same general area	praise "no" + reason prompt	neutral "no" probe

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Hi) Living things (plants and animals) live in specific areas we call <u>habitats</u>. An example of a habitat would be the shady moist areas under trees and shrubs where mushrooms and sow bugs live. What is an example of another habitat and some of the plants and animals that might live there? ridge of foothills (redwoods, pines, hawks, small birds, deer) salt marshes, (grasses, sea birds, crabs)	(Lo) When we talk about populations we mean populations of living things. What are the two kinds of living things that form populations? plants and animals	praise "no" + reason prompt	neutral "no" probe
			What do we call the living area that populations exist in? habitat		

377

St+	St-	Sc+	Sc-
Populations that share the same habitat are in a community. Examples of habitats are: 1. The ridge of the foothills (ever notice the heavier forests as you go up the foothills to the top?) Climate: a. heavier moisture b. cooler (more fog, rain) Type of life: c. plants (redwoods, pines) d. animals (deer, hawk) 2. Salt marshes along bay: Climate: a. drier (less rain b. saltwater Type of life: c. plants (grasses, few trees) d. animals (sea birds, crabs) Different plants and animals live in these habitats--they form different communities.	Populations that share the same habitat are in a community. Examples of habitats are: 1. The ridge of the foothills (ever notice the heavier forests as you go up the foothills to the top?) Climate: a. heavier moisture b. cooler (fog,rain) Type of life: a. plants (redwoods, pines) d. animals (hawk, deer) 2. Salt marshes along bay: a. drier (less rain) b. salt water c. plants (grasses, few trees) d. animals (sea birds, crabs) Different plants and animals live in these habitats--they form different communities.		

St+	St-	Sc+	Sc-	Rc+	Re-
		(Hi) In the last example I gave of the salt marsh, <u>how</u> do you think the plants and animals depend on each other? Example--small fish depend on grasses for food and protection, but seagulls eat small fish (combined relationship)	(Lo) Do plants and animals that live in the same habitat depend on each other? yes Example--small fish depend on grasses for food and protection, but seagulls eat small fish (combined relationship)	praise "no" + reason prompt	neutral "no" probe
		(Hi) Do you think the plants (like the grasses) that live in the salt marsh can live in the forest habitat of the foothills? Why/why not? no, they are adapted to a different habitat; could not live in: hard soil, cooler temp., salt vs. fresh water.	(Lo) Do plants and animals that depend on each other and live in the same general area belong to the same community? yes Plants and animals adapt themselves to habitats, they have a hard time living in other habitats. Example: plants ada to saltwater in salt marsh could not live in hard soil with fresh water.	praise "no" + reason prompt	neutral "no" probe

379

St+	St-	Sc+	Sc-
Let's summarize what we've talked about so far. animal and plant <u>populations</u> sharing the same <u>habitat</u> and dependent on each other are in a community (On board) 1. Populations 2. Habitats 3. Communities	There are many different kinds of habitats. Some of the factors that are important in habitats are climate (temperature, and moisture), exposure to the sun, kind of soil, and other factors in the non-living world. Some habitats are very small, others are bigger. For example, some kinds of insects, like sow bugs, like to live in cool, wet places. But these places also have to be tight, like cracks in rocks, or underneath rocks. They will not live in cool, wet places that are not tight, like the shadow of a cliff where the sun never shines but where there are no cracks.		
Let's move on to an <u>important</u> part of our definition of a community. Let's talk about what it means to be <u>dependent</u>.			

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Hi) Can you think of a predator-prey relationship mentioned in today's reading? e.g. fox-squirrel fox-chicken fox-mice	(Lo) The reading said that squirrels live near trees? Why? food, nest in tree		
		(Hi) How are predator-prey relationships (like the fox-squirrel) examples of how living things in a community are dependent on each other? e.g. - all predator-prey relationships are food relationships, need for food, etc.	(Lo) The reading also said that grey foxes live nearby. Is there any dependence between the squirrel and the grey fox? How? yes, food		
			(Lo) The grey fox and the squirrel are in a predator-prey relationship. Was there anything else mentioned in the reading that the grey fox would prey on this habitat? What? yes, mice, quail, chickens	praise "no" + reason prompt	neutral "no" probe
		(Hi) Who can give an example of a food chain that would be in the foothills? Which living things are dependent on other living things in this food chain? e.g., berries→quail →fox	(Lo) What other living things were mentioned that also live and grow in the foothills? birds, bushes, berries, insects, etc.		

381

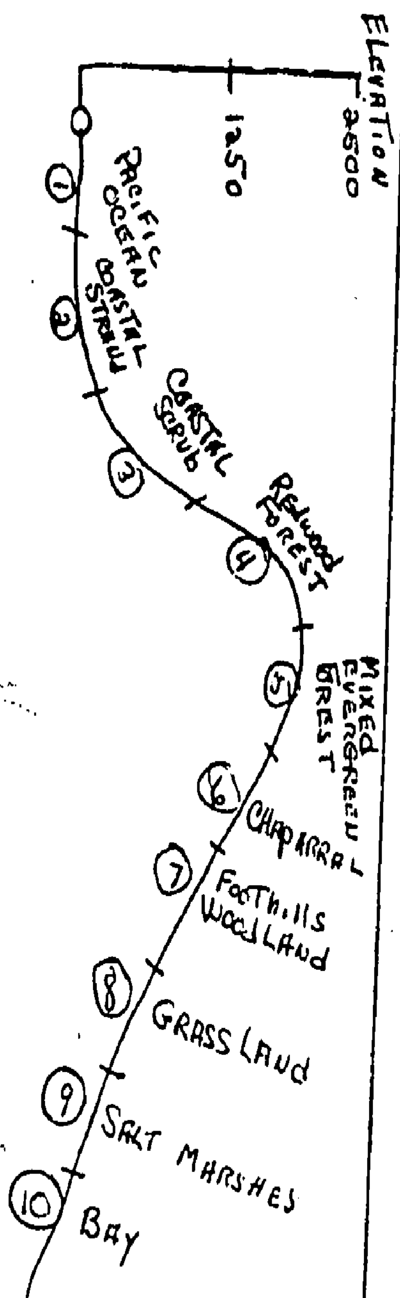
St+	St-	Sc+	Sc-	Rc+	Re-
		OK. Dependence has to do with one living thing eating another living thing, or it could mean that one living thing depends on another for shelter, like a mushroom depending on an oak for shade.	(Lo) Some of these animals eat plants, some animals eat other animals. What do we call this chain of animal eating plant, animal eating animal? food chain, food web		
		(Hi) Is there any way that animals that are preyed upon by other animals can be dependent on their predators? For example: Are squirrels dependent on foxes, or are mice dependent on hawks? yes, predators eat old, sick, weak animals; keep size of population low.	OK. Dependence could be one living thing eating another living thing, or it could mean that one living thing depends on another for shelter, like a mushroom depending on an oak for shade.	praise "no" + reason prompt	neutral "no" probe
			(Hi) Is there any way that animals that are preyed upon by other animals can be dependent on their predators? For example, are squirrels dependent on foxes, or are mice dependent on hawks? yes, predators eat old, sick, weak animals; keep size of population low.		

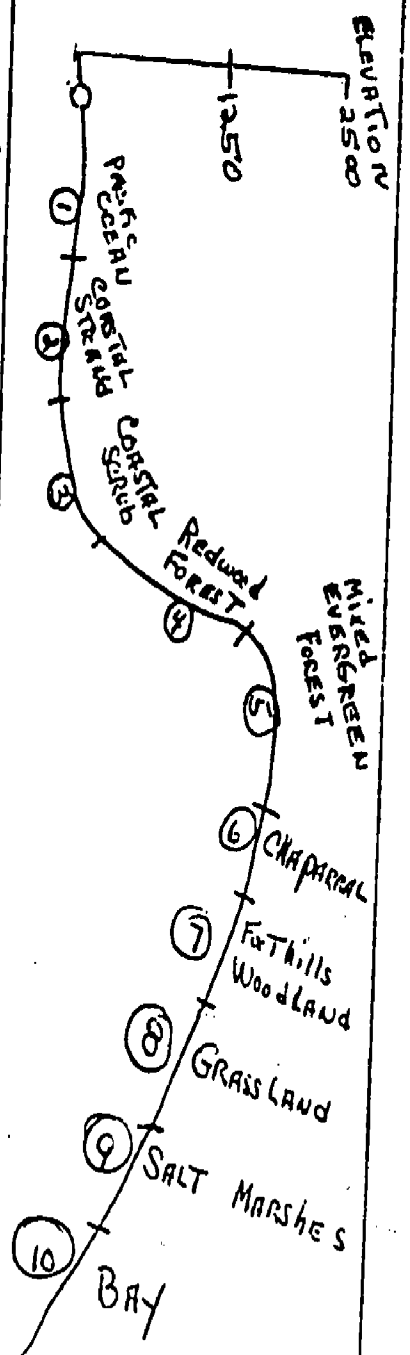
St+	St-	Sc+	Sc-	Rc+	Re-
The dependencies in a community are very complex. Not only are predators dependent on their prey, but prey are ultimately dependent on their predators. E.g., there used to be many sea otters off the west coast of the USA. The otters ate sea urchins. In turn, the sea urchins ate giant kelp. Otters were killed for their beautiful fur. Then the sea urchins multiplied until they ate all the kelp. If this continued, eventually, the kelp would disappear; and eventually the urchins would disappear too because they would starve.	The dependencies in a community are very complex. Not only are predators dependent on their prey, but prey are ultimately dependent on their predators. E.g., there used to be many sea otters off the west coast of the USA. The otters ate sea urchins. In turn, the sea urchins ate giant kelp. Otters were killed for their beautiful fur. Then the sea urchins multiplied until they ate all the kelp. If this continued, eventually the kelp would disappear; and eventually the urchins would disappear too because they would starve.				
		(Hi) Can you think of anything the sea urchins could do to keep from starving? eat other things migrate	(Hi) Can you think of anything the sea urchins could do to keep from starving? eat other things migrate	praise "no" + reason prompt	neutral "no" probe

383

St+	St-	Sc+	
The sea otter example shows how complex communities can be. It would be even more complex if we talked about all the other plants and animals that depend on the kelp. Even the ecosystem on the shore is affected, since the giant kelp changes the way in which waves hit the shore.	The sea otter example shows how complex communities can be. It would be even more complex if we talked about all the other plants and animals that depend on the kelp. Even the ecosystem on the shore is affected, since the giant kelp changes the way in which waves hit the shore. If there were no kelp at all, the waves might break on the shore with more force, which would change the shoreline and alter the communities of plants and animals that are on the shore.		
In summary, the dependencies in a community are very complex. 1. Predators depend on prey for food 2. Prey depend on predators to get rid of weak, sick, etc. 3. Animals depend on plants for food, shelter.			

St+	St-	Sc+	Sc-
Now that we've talked generally about what communities are, let's look at the ten communities of the foothills area.	This is a picture of the ten communities of the foothills area.		





St+	St-	Sc+	Sc-	Rc+	Rc-
		(Hi) Look at the names of some of these communities, (redwood forest, grassland, foothill woodland). What do you think is the most important factor in naming a community? plants that live in that community	(Lo) Most communities are named after the major plant in that area. For example, the grassland community is so named because the dominant plant is grass. How do you think the redwood forest community got its name? primarily redwood trees	praise "no" + reason prompt	neutral "no" probe
		(Hi) Why do you think that communities are usually named after the major plants in them? plants are more stable, do not move (spread) as fast, do not migrate animals migrate or die out faster, are not as stable, live shorter lives.	Communities are not named after animals because animals are not as stable as plants. They migrate and die off faster, and tend not to live as long. For example, the redwoods live for hundreds of years, but animals don't. Animals come and go but the redwoods are still here after many centuries.		
As we talked about earlier, there are many factors that determine what plants exist in a community. One such factor is elevation, or how much above sea level the community is.	There are many factors that determine what plants exist in a community. One such factor is elevation, or how much above sea level the community is.				

386

St+	St-	Sc+	Sc-	Rc+	Re-
Other factors are related to climate, like temperature and the amount of moisture.	Other factors are related to climate, like temperature and the amount of moisture.				
		(Hi) What are some other factors that might determine the kind of plant community that might live somewhere? light, soil type, fires, competition with other plants, etc. Competition between communities.	(Hi) What are some other factors that might determine the kind of plant community that might live somewhere? light, soil type, fires, competition with other plants, competition between communities	praise "no" + reason prompt	neutral "no" probe
Let's pick out one of the communities of the foothills, and look at it more closely. Let's look at the plants and animals that live there, and how they depend on each other. Let's look at the chaparral. Much of the chaparral around here is mixed with blue oak. We will see later that this mixture is related to an important concept about communities. This concept is succession.	The chaparral is one of the ten communities of the foothills. Many of the examples we have discussed come from the chaparral. Much of the chaparral around here is mixed with blue oak, but we'll talk about it right now as if it were just chaparral.				

St+	St-	Sc+	Sc-
Some of the major plants of the chaparral are: (On board) Manzanita (bush) Scrub oak (tree) Chemise (bush) other scrubby plants Topographical characteristics: (What the land is like) (On board) well-drained south-facing slopes Major animals: grey foxes chipmunks thrashers wrens Chaparral communities exist where the summers are dry and the winters are wet.	Some of the major plants of the chaparral are: (On board) Manzanita (bush) Scrub oak (tree) Chemise (bush) other scrubby plants Topographical features: (What the land is like) well-drained south-facing slopes Major Animals: grey foxes chipmunks thrashers wrens Chaparral communities exist where the summers are dry and the winters are wet.		

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Lo) Why are there chaparral communities here? wet winters, dry summers	(Lo) Why are there chaparral communities here? wet winters, dry summers		
		(Lo) Chaparral communities could not live in the desert because it 's too dry, they couldn't live in Washington State because the summers are wet. What kind of climate is necessary for chaparral to exist? wet winters, dry summers	(Lo) Chaparral communities could not live in the desert because it is too dry; they couldn't live in Washington State because the summers are wet. What kind of climate is necessary for chaparral to exist? wet winters, dry summers	praise "no" + reason prompt	neutral "no" probe
		(Lo) Are there any penguins or seals living in the chaparral? no	(Lo) Are there any penguins or seals living in the chaparral? no		
These kinds of animals are adapted to different habitats. They live in different communities.	These kinds of animals are adapted to different habitats. They live in different communities.				
Animals and plants live in certain areas because they are well adapted to the habitat. And the community of the chaparral is well adapted to this area. E.g., scrub oak; small leaves, less evaporation in long, dry summers. (ERASE BOARD)	Animals and plants live in certain areas because they are well adapted to the habitat. And the community of the chaparral is well adapted to this area. e.g., scrub oak - small leaves, less evaporation in long, dry summers. (ERASE BOARD)				

389

St+	St-	Sc+	Sc-	Rc+	Re-
		(Lo) What were the major plants of the chaparral? scrub oak, chemise, manzanita, other scrubby plants	(Lo) What were the major plants of the chaparral? scrub oak, chemise, manzanita, other scrubby plants	praise	neutral
		(Lo) What are the important features of the land in the chaparral? well drained; south-facing slopes	(Lo) What are the important features of the land in the chaparral? well drained; south-facing slopes	"no" + reason	"no"
		(Lo) What are some major animals of the chaparral? grey fox, chipmunks, thrasher, wren	(Lo) What are some major animals of the chaparral? grey fox, chipmunk, thrasher, wren		
		(Lo) What kind of climate does chaparral need? wet winter, dry summer	(Lo) What kind of climate does chaparral need? wet winter, dry summer	prompt	probe
Let me summarize what we know of the chaparral, which is one of the major communities of the foot-hills: - climate - topography - plants - animals					

390

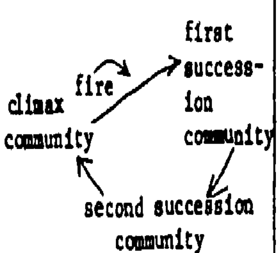
512 513

St+	St-	Sc+	Sc-	Rc+	Re-
Using the chaparral as an example, we'll now talk about two important concepts: Climax Community Ecological Succession	Ecological communities change--they succeed each other until the best adapted community is reached the climax community				
		(Lo) What are some of the things that cause communities to change that were mentioned in the reading? disease, fire	(Lo) What are some of the things that cause communities to change that were mentioned in the reading? disease, fire	praise "no" + reason prompt	neutral "no" probe
Chaparral is changed by both. oak moth larvae kill oaks fires burn away trees and bushes	Chaparral is changed by both. oak moth larvae kill oaks fires burn away trees and bushes				
Communities like chaparral continually change until a community that is most adapted to a habitat develops. Then this community tends not to change.	Communities like chaparral continually change until a community that is most adapted to a habitat develops. Then this community tends not to change.				

391

St+	St-	Sc+	Sc-	Rc+	Rc-
This kind of community is called a climax community. A climax community is so well adapted to a habitat that it usually stays the way it is. The chaparral in the foothills is a climax community.	This kind of community is called a climax community. A climax community is so well adapted to a habitat that it usually stays the way it is. The chaparral in the foothills is a climax community.				
		(Lo) But I did mention two things that can change the chaparral. What were these two things? disease/oak larvae; fire	(Lo) But I did mention two things that can change the chaparral. What were these two things? disease/oak larvae; fire	praise "no" + reason prompt	neutral "no" probe
After a fire sweeps through the chaparral, and the trees and scrubs are burnt, new plants start to grow (like grasses). These new plants attract new animals. A new kind of community begins. (E.g., a grassland community). We call this a succession community.	After a fire sweeps through the chaparral, and the trees and scrubs are burnt, new plants start to grow (like grasses). These new plants attract new animals. A new kind of community begins. (E.g., grassland community). We call this a succession community.				

392

St+	St-	Sc+	Sc-	Re+	Re-
It is called a succession community because it will change (new communities will succeed it) until it again becomes a climax community.	It is called a succession community because it will change (new communities will succeed it) until it again becomes a climax community.				
Here's a diagram that shows the cycle of succession from one community to another: 	The cycle of succession looks like this: 				
		(Lo) What is the name of a climax community in the foothills? chaparral	(Lo) What is the name of a climax community in the foothills: chaparral	praise	neutral
		(Hi) What do you think would happen if oak moth larvae killed all the oak trees in the chaparral? E.g., concept of success-ion back to climax--ask for specific examples "no shade from trees," "no acorns for birds, squirrels, etc."	(Hi) What do you think would happen if oak moth larvae killed all the oak trees in the chaparral community? E.g., concept of success-ion back to climax--ask for specific examples, "no shade from trees," "no acorns for birds, squirrels, etc."	"no" + reason prompt	"no" probe

St+	St-	Sc+	Sc-
Let me review everything we talked about today. 1. Populations of plants and animals form communities (give example) 2. Communities may include several habitats. (climate, etc.) 3. There are ten communities in the foothills 4. Communities change adaptation succession climax			

Lesson VIII. Ecosystems

St+	St-	Sc+	Sc-
Before we get into today's lesson about ecosystems, let's briefly review what we talked about yesterday on the topic of communities. 1. Communities are populations of plants and animals which are interdependent. 2. Communities live in habitats. (Climate, soil, etc.) 3. There are 10 communities in the foothills. 4. Communities change --succession and climax			

St+	St-	Sc+
There are 4 major objectives for today's lesson: 1. define the term <u>ecosystem</u> 2. describe the parts that make up an ecosystem 3. examine relationships between living things and non-living things 4. describe the term <u>biome</u> and compare this idea with the idea of an ecosystem		
OK, those are the basic goals for the lesson. Let's begin to get into the topic of ecosystems by me outlining some of the material.		

Re- | +

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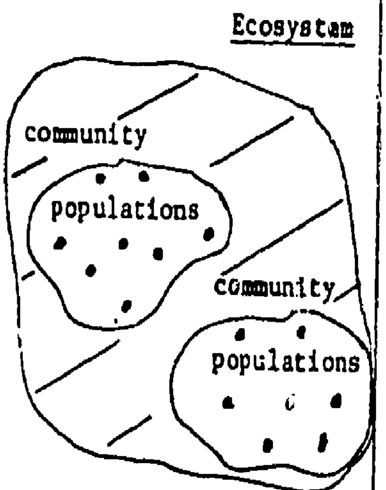
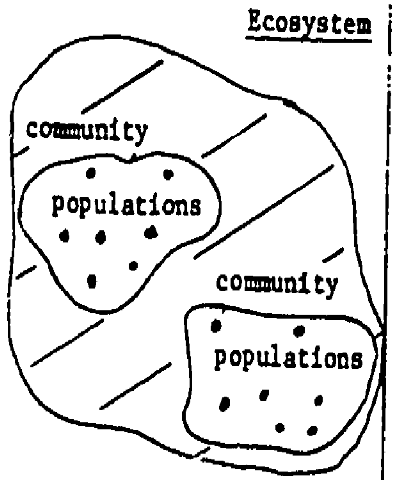
St+	St-	So+	So-
1. ecosystem - the set of relationships between a. living things--population A, population B, ... (community) and b. non-living things-- (1) climate (2) soil 2. living things--we've explored these intensively for the last 7 lessons; we'll look at them today from the perspective of their relationships to non-living things 3. non-living things-- a. climate, for example (1) temperature (2) moisture (3), (4) 2 more I'll talk about later in the lesson b. soil, for example (1) nutrients, like nitrogen (2) ability to hold water			

St+	St-	Sc+	Sc-	Rc+	Rc-
Let's get into the lesson now by looking at the parts of an ecosystem. This will be mostly review from the lessons for the last 2 days.	In this lesson, we're going to talk about ecosystems and what they are.				
		(Lo) What is a definition of the ecological term population? 1. living things 2. single species 3. live in same general geographic area	(Lo) What is a definition of the ecological term population? 1. living things 2. single species 3. live in same general geographic area	praise "no" + reason prompt	neutral "no" probe
		(Lo) And what do we mean by the term community? 1. several populations of living things 2. all dependent on each other to some degree 3. in same general geographic area	(Lo) And what do we mean by the term community? 1. several populations of living things 2. all dependent on each other to some degree 3. in same general geographic area	praise "no"+ reason prompt	neutral "no" probe

398

<table>
<tr><th>St+</th><th>St-</th><th>Sc+</th><th>Sc-</th></tr>
<tr><td>OK, let me put a diagram on the board showing populations and communities.</td><td></td><td></td><td></td></tr>
<tr><td>


Each dot represents a population, e.g., field mice, black snakes, grains like wild wheat, birds, and so on.
The populations that are interdependent or all interacting form a community.

Notice that there is some more space in addition to populations and communities that makes up a whole ecosystem--the space marked off by the diagonal lines.
</td><td>


Each dot represents a population, e.g., field mice, black snakes, grains like wild wheat, birds, and so on.

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Notice that there is some more space in addition to populations and communities that makes up a whole ecosystem--the space marked off by the diagonal lines.
</td><td></td><td></td></tr>
</table>

St+	St-	Sc+	Sc-	Rc+	Re-
		(Hi) What might go in the space with the lines to finish labeling the parts of the ecosystem? 1. climate a. moisture b. temperature c. wind d. energy from the sun 2. soil a. nutrients b. ability to hold water	(Lo) What was one of the non-living things that could go into the space with lines? 1. climate a. moisture b. temperature 2. soil a. nutrients b. ability to hold water	praise "no" + reason prompt On board  climate or what-ever	neutral "no" probe
		(Hi) What is another thing that could be a part of the ecosystem here? - as above - repeat until 3 answers have been given all together	(Lo) What was one of the other non-living things related to climate (soil) that we could put into the diagram of the ecosystem? as above repeat until 3 answers have been given all together	praise "no" + reason prompt On board: as above	neutral "no" probe
OK, let's talk about the non-living parts of ecosystems for a few moment .					

400

St+	St-	Sc+	Sc-
There are 4 major things about the climate that have a lot of influence on how the ecosystem works. You read about 2 of these today: moisture, temperature } on board if not already Remember I said I'd talk about 2 more factors in the climate of an ecosystem in the outline? They are: wind, sun energy } on board Let's explore how these 4 non-living things influence the ecosystem and the relationships we find in it.	Those are some of the non-living things in an ecosystem. Some other non-living things that influence the relationships in the ecosystem are: climate { moisture, temperature, wind, sun energy } put on board whatever isn't already there soil { nutrients, ability to hold water }		
Let me ask you a few questions about these non-living things in ecosystems.			

St+	St-	Sc+	Sc-	Rc+	Re-
		(Lo) What 3 things help determine the temperature of a place in an ecosystem? 1. distance from the equator (latitude) 2. altitude 3. distance from oceans or large bodies of water	(Lo) What 3 things help determine the temperature of a place in an ecosystem? 1. distance from the equator (latitude) 2. altitude 3. distance from oceans or large bodies of water	praise "no" + reason prompt On board:	neutral "no" probe
		(Lo) And what factors influence how much moisture in the form of rain or snow or dew will fall on an area in the ecosystem? 1. distance from large body of water 2. lay of the land--topography (e.g., mountains)	(Lo) And what factors influence how much moisture in the form of rain or snow or dew will fall on an area in the ecosystem? 1. distance from large body of water 2. lay of the land--topography (e.g., mountains)	praise "no" + reason prompt On board:	neutral "no" probe
OK - that takes care of what you read about non-living things that influence ecosystems. Let's look at the 2 new factors I mentioned earlier--wind and sun energy					

402

561

St+	St-	Sc+	Sc-	Re+	Re-
		(Hi) How do you think wind might affect an ecosystem? 1. winds carry pollen for plants to make seeds 2. winds carry seeds like maple tree helicopter seeds and spores from mushrooms and puff balls 3. wind erodes topsoil--blows it away 4. wind transports water vapor	(Lo) Have you ever blown the white fuzz of a dandelion plant and watched them drift in the wind? yes The white umbrella shaped things are dandelion seeds that the wind carries. Since dandelions, and other plants like maple trees, depend on the wind to carry their seeds to places where they can grow, why is wind important as a non-living thing in the ecosystem? it carries seeds for plants	praise "no" + reason prompt on board	neutral "no" probe
		(Hi) Can you think of another way wind could influence an ecosystem? from above	(Lo) We also know that wind can blow away topsoil that many plants root in. So how else might wind influence an ecosystem? erode topsoil	praise "no" + reason prompt On board	neutral "no" probe
There are 2 other ways besides these that wind influences an ecosystem.					

403

St+	St-	Sc+	Sc-
Wind is an influence on the ecosystem because it: 1. carries seeds, to move them to places where they can grow 2. carries pollen so plants can make seeds 3. erodes soil that plants root in 4. transports water vapor from place to place and partly controls how fast water evaporates into the air ...choose those not already on board ...add to board those not already there	Wind can also affect an ecosystem because it: 1. carries pollen for plants to make seeds 2. transports water vapor from place to place and partly controls how fast water evaporates into the air		
Remember I said there were 2 factors in the non-living world that affect ecosystems that you didn't read about. We've already discussed one--wind. The second one is sun energy or sunlight. On board: sun energy--sunlight	Another factor from the non-living world that influences ecosystems is sun energy or sunlight.		

St+	St-	Sc+	Sc-	Rc+	Re-
		(Hi) How does sun energy affect all living things in the ecosystem? 1. producers need sun energy for photo-synthesis to make food 2. other animals use sun energy indirectly when they consume food from plants--the food chain idea 3. all living things need warmth from the sun to keep temperatures within a range for life activities	(Lo) Why do producers need sun energy? to make food by photo-synthesis	praise "no" + reason prompt	neutral "no" probe
			(Lo) And since 1st order con-sumers eat producers, why do the consumers need sun energy? so they have food in the form of plants (producers)	praise "no" + reason prompt	neutral "no" probe
			(Lo) And since the sun provides energy to keep the earth warm, why do all living things need sun energy? to keep temperatures within a range for life activities	praise "no" + reason prompt	neutral "no" probe

405

St+	St-	Sc+	Sc-	Re+	Re-
OK - that takes care of the factors in climate that are non-living and have an effect on the ecosystem. Let's just review them for a second: 1. temperature 2. moisture (these were in the reading) 3. wind 4. sun energy (I just presented these in the lesson)					
Let's go on now to think about the soil as a non-living factor that affects the ecosystem.	The soil is a non-living factor that has an effect on the ecosystem.				
		(Hi) How does the soil influence living things in the ecosystem? 1. nutrients available in soil determine how favorable soil is for plant growth, thus 1st order consumers, etc.--food chain idea 2. ability to hold water determines what kind of plants (producers) can grow, thus influencing what kind (Contd)	(Lo) What's one thing about the soil that affects the ecosystem? 1. nutrients 2. ability to hold water Now since the ability to hold water and the nutrients available determines how many and what kind of plants grow, does it have an effect on 1st order consumers too? yes And so these also influence the whole food chain.	praise "no" + reason prompt On board food chain idea	neutral "no" probe

406

568

537

St+	St-	Sc+	Sc-
		(Cont'd) of animals can be 1st order consumers, etc.--food chain idea.	
OK - let's review for a moment. There are 2 major groups of non-living things that influence the eco-system--each has several aspects to it. 1. climate a. temperature b. moisture c. wind d. sun energy 2. soil a. nutrients b. ability to hold water On board: (the above)			
Remember I said that these non-living things have effects on ecosystems. A better way to put this idea is that non-living things affect <u>relationships</u> in <u>ecosystems</u>. On board: <u>relationships</u> ↓ ecosystem	Non-living factors really affect relationships in ecosystems.		

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Hi) Can you give me an example of how a non-living thing affects a relationship in an ecosystem? any will do, but must include: 1. non-living factor 2. 2 or more living things (e.g., food chain) 3. what happens to the relationship if the non-living thing changes	(Lo) If all of a sudden the wind changed its direction so that it no longer picked up evaporated water from a lake, the rain would decrease in the area. What would this have an immediate effect on? producer	praise "no" + reason prompt on board	neutral "no" probe
			(Lo) And what comes after a producer in the food chain? 1st order consumer	praise "no" + reason prompt	
			(Lo) And after that? 2nd order consumer	praise "no" + reason prompt	
			(Lo) So if the rain changed the producers in an area and this had an effect on 1st order consumers, which in turn affected 2nd order consumers, would the relationship of the food chain be affected? yes	praise "no" + reason prompt	
So the really important thing is that non-living things affect <u>relationships</u> in the <u>ecosystem</u> On board					

408

St+	St-	Sc+	Sc-
All these things we've been talking about are the parts of an ecosystem. 1. living things a. populations b. communities 2. non-living things a. climate b. soil And the important point is that non-living things affect the relationships between living things.	The parts of an ecosystem are the living things and non-living things. Non-living things have an influence on the relationships between these parts.		
You read about how rabbits had adapted to the complete ecosystem--especially the non-living aspect of temperature, by having ears of different lengths to help regulate their body temperatures. Let's look at this idea of adapting more closely. On board: adapt			

St+	St-	Sc+	Sc-	Rc+	Rc-
Animals and plants adapt to the living and non-living characteristics of ecosystems. One way this happens is by physical evolution. On board: evolution This means that living things change their bodies to be able to survive in an ecosystem or take advantage of a characteristic of the ecosystem. The rabbits we mentioned changed the length of their ears. This adaptation took many, many generations of rabbits. But eventually all the rabbits of one population, like desert jack rabbits, grew long ears to help them live better in their ecosystem.	Animals and plants adapt to the living and non-living characteristics of ecosystems. One way this happens is by physical evolution. This means that living things change their bodies to be able to survive in an ecosystem or take advantage of a characteristic of the ecosystem. The rabbits grew longer ears to regulate heat loss. This adaptation took many, many generations of rabbits. But eventually, all the rabbits of one population, like desert jack rabbits, grew ears to help them live better in the ecosystem.				
		(Hi) Can you think of other examples of evolution in animals that helped them adapt to their ecosystem? 1. heavier fur in winter 2. color camouflage, like partridge, snakes etc.	(Hi) Can you think of other examples of evolution in animals that helped them adapt to their ecosystem? 1. heavier fur in winter 2. color camouflage, like partridge, snakes, etc.	praise "no" + reason prompt On board	neutral "no" probe

St+	St-	Sc+	Sc-	Rc+	Rc-
Let's look at another way living things adapt to their ecosystems, this one by changing the way they act.					
		(Lo) What do birds like robins do every fall and spring? migrate south/north	(Lo) What do birds like robins do every fall and spring? migrate south/north	praise "no" + reason prompt On board	neutral "no" probe
		(Hi) Why do they migrate--what changes in their ecosystems make migration an adaptive action? 1. cold weather reduces food supply, energy flow in the ecosystem	(Lo) When the cold weather comes, forcing a change in the food chain and the energy flow, would moving to warmer climates where the robins can get more food be a way to adapt? yes	praise "no" + reason prompt On board	neutral "no" probe
The act of migration is an adaptation to non-living factors in the ecosystem. So is hibernation, like bears do. Living things adapt to their habitat or the combination of living and non-living factors that influence their lives. On board: habitat	The act of migration is an adaptation to non-living factors in the ecosystem. So is hibernation, like bears do. Living things adapt to their habitat, or the combination of living and non-living factors that influence their lives.				

411

St+	St-	Sc+	Sc-
All plants and animals adapt to the living and non-living factors in their ecosystems.	All plants and animals adapt to the living and non-living factors in their ecosystems.		
Now, let's turn to how ecologists describe the major regions of habitats.			
An ecosystem is a set of orderly relationships in ecology. A habitat, on the other hand, is a small geographical area characterized by an ecosystem--a system of ecological relationships. These smaller areas or habitats however, can be grouped together to make a <u>biome</u>. On board: biome	An ecosystem is a set of orderly relationships in ecology. A habitat, on the other hand, is a small geographical area characterized by an ecosystem--a system of ecological relationships. These smaller areas or habitats, however, can be added up to a biome.		
Let's see what a biome really is.			

St+	St-	Sc+	Sc-
Biomes are large geographic regions composed of roughly the same kinds of habitats and having the same general kinds of ecological relationships, that is, ecosystems. Biomes are usually named after the dominant kind of plants. For example, the plains of middle America have mostly grasses--they're called the grasslands biome. Most of the New England states have a lot of trees that lose their leaves in the winter--deciduous trees--and so this large area is called the deciduous forest biome.	Biomes are large geographic regions composed of roughly the same kinds of habitats and having the same general kinds of ecological relationships, that is, ecosystems. Biomes are usually named after the dominant kind of plants. For example, the plains of middle America have mostly grasses--they're called the grasslands biome. Most of the New England states have a lot of trees that lose their leaves in the winter--deciduous trees--and so this large area is called the deciduous forest biome.		

St+	St-	Sc+
There are many different communities in a biome. For example, most of northern California is in a coniferous forest biome. Yet we know that there are chaparral and grassland communities around here. So we can see that there can be many different kinds of communities in a biome.	There are many different communities in a biome. For example, most of northern California is in a coniferous forest biome. Yet we know that there are chaparral and grassland communities around here. So we can see that there can be many different kinds of communities in a biome.	

579

St+	St-	Sc+	Sc-
Let's review the material in this lesson: 1. definition of ecosystem--the (system-set) of relationships between living things and non-living things 2. non-living things that influence relationships in the ecosystem a. climate (1) temperature (2) moisture (3) wind (4) sun energy b. soil (1) nutrients (2) ability to hold water 3. how animals adapt to their ecosystems a. evolution b. behavior change, for example, migration--as an example of changing their action--also hibernation 4. habitat--physical setting of an ecosystem 5. biome--large geographic areas named after dominant form of plant life			

St+	St-	Sc+
We've spent the last 8 days exploring the science of ecology. Yesterday, we studied about ecosystems. Let's briefly review what we learned yesterday. 1. definition of ecosystem--the (system-set) of relationships between living things and non-living things. 2. non-living things that influence relationships in the ecosystem a. climate (1) temperature (2) moisture (3) wind (4) sun energy b. soil (1) nutrients (2) ability 3. how animals adapt to their ecosystems a. evolution b. migration 4. habitat--local combination of living and non-living factors 5. biome--large geographic areas named after dominant form of plant life		

St+	St-	Sc+	Sc-
Today, you read about the special role that humans play in changing an ecosystem. With this description as background, we'll try to accomplish 3 things today: 1. briefly review what we've learned about ecology in all the preceding lessons, 2. apply this learning to describe the changing of Peaceful Lake from an ecological perspective, and 3. try to use what we know about ecology in general to judge whether we should change the ecology of Peaceful Lake, if we could, to an ecosystem with different characteristics. This will involve that we make some difficult choices and be wise in deciding to look at the ecosystem of Peaceful Lake from one viewpoint as opposed to another.			

St+	St-	Sc+
Let's start out with a brief outline of our tasks for the lesson: 1. we'll review major concepts in ecology a. ecology--its definition b. what a relationship is c. the role of energy in the ecosystem d. populations and factors that affect their size e. communities f. the idea of ecosystems 2. in describing how the ecosystem around Peaceful Lake was affected by humans, we'll focus on how <u>relationships</u> were <u>changed</u> and how the ecosystem tried to restore its balance even though humans were changing the original relationships 3. in judging whether we'd like to change the ecosystem of Peaceful Lake, we'll have to decide what <u>standards</u> we'll use to measure how good our alternatives to the current ecosystem are.		

St+	St-	Sc+	Sc-	Rc+	Re-
First, let's review some ecological principles and definitions.	Today, we're going to talk about ecology in general and humans' role in changing the ecosystem of Peaceful Lake.				
		(Lo) What's the definition of ecology? the science of relationships between living things and non-living things	(Lo) What's the definition of ecology? the science of relationships between living things and non-living things	praise "no" + reason prompt On board: science relationships living things non-living things	neutral "no" probe
		(Lo) And what are the two characteristics that define a relationship? 1. 2 or more parts 2. one part has an effect on another	(Lo) And what are the two characteristics that define a relationship? 1. 2 or more parts 2. one part has an effect on another	praise "no" + reason prompt	neutral "no" probe
		(Hi) What's the difference between the way matter and energy are used or incorporated into relationships? 1. matter is cycled, used again 2. energy is unidirectional, not cyclable	(Lo) What's the word we use to describe the one-way flow of energy in ecological relationships? unidirectionality	praise "no" + reason prompt On board	neutral "no" probe
			(Lo) And what's the word we use to describe the way matter moves through ecological relationships over and over again? cycles	praise "no" + reason prompt On board	neutral "no" probe

419

St+	St-	Sc+	Sc-	Rc+	Rc-
And we also learned that energy is the key to ecological relationships, the thing that starts them and maintains them in an ecosystem.	And we also learned that energy is the key to ecological relationships, the thing that starts them and maintains them in an ecosystem				
Let's turn now to the information we've studied about living things in populations and communities.					
		(Hi) What are some reasons that the size of a population increases or decreases and how do these factors affect population size? 1. migration in 2. birth rate 3. adaptation reasons for increases 4. migration out 5. predators 6. starvation, decreases of needed resources reasons for decreases	(Lo) Name 3 things that decrease the size of populations: 1. migration out 2. predators 3. starvation--decrease of needed resources	praise "no" + reason prompt On board	neutral "no" probe
			(Lo) Can you name 3 reasons why the size of populations would increase? 1. migration in 2. birth rate 3. adaptation	praise "no" + reason prompt On board	neutral "no" probe
Now let's see what the relations are between populations and communities.					

St+	St-	Sc+	Sc-	Rc+	Re-
		(Lo) What is our definition for a community? dynamic interdependence of several populations living in the same general geographic area	(Lo) What is our definition for a community? dynamic interdependence of several populations living in the same general geographic area	praise "no" + reason prompt	neutral "no" probe
		(Hi) Do changes in one population have an effect on a community? Why? yes--because that population is part of the set of relationships so that a change in its role results in a change in the relationships it is immediately involved in which change other relationships connected to the first ones, etc.	(Lo) So, does a change in one population affect the whole community? yes	praise "no" + reason prompt	neutral "no" probe
We call this kind of event where changes in one population have influences on changes in other populations, which in turn influence changes in other populations, a <u>ripple effect</u>. On board: <u>ripple effect</u>	We call this kind of change where changes in one population have influences on changes in other populations, which in turn influence changes in other populations a ripple effect.				

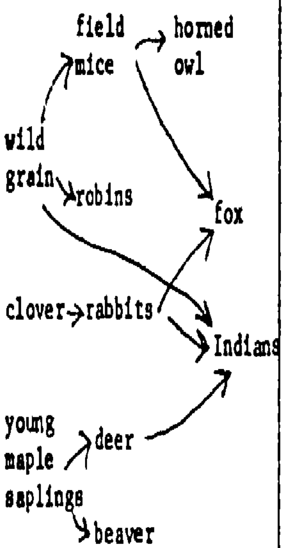
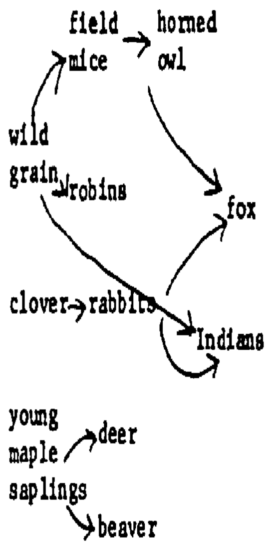
421

St+	St-	Sc+	Sc-	Rc+	Re-
OK, one final point of review before we get into the application of ecology to discussing Peaceful Lake.					
		(Hi) What's the difference between a habitat and an ecosystem? 1. ecosystem=set of ecological relationships that are orderly and generally true 2. habitat=the specific area that a population lives in that is characterized by an ecosystem	(Lo) What is the definition of an ecosystem? ecosystem--set of ecological relationships that are orderly and generally true	praise "no" + reason prompt On board	neutral "no" probe
			(Lo) What is the definition of a habitat? a specific area that a population lives in that is characterized by an ecosystem	praise "no" + reason prompt on board	neutral "no" probe
Before we get into the lesson itself, let me briefly review things so far. We've talked about 1. definition of ecology 2. what a relationship is 3. energy and its flow in ecosystems 4. populations, communities, and the important idea of a ripple effect 5. the ideas of ecosystems and habitats					

422

St+	St-	Sc+	Sc-	Rc+	Rc-
Let's move on now to apply our knowledge about ecology to describe changes in Peaceful Lake. After we do this, we'll discuss whether humans ought to try to change this ecosystem and community in some other ways.					
		(Hi) Were the Indians who lived around Peaceful Lake for several hundred years changing the ecosystem relationships or were they part of the "original" ecosystem? Why? probably part of the "original" ecosystem because they had lived the same way for several centuries.	(Lo) Did the Indians who lived around Peaceful Lake and who had been there for several hundred years drastically change the ecosystem? no	praise "no" + reason prompt	neutral "no" probe
So the first real changes in the habitat and ecosystem of Peaceful Lake probably occurred when the fur trappers moved in.	The fur trappers were the first real force to start changing the habitat and ecosystem of Peaceful Lake.				

423

St+	St-	Sc+	Sc-	Rc+	Re-
Here's a small piece of the food web that probably existed before trappers entered the scene. On board: 	Here's a small piece of the food web that probably existed before the trappers entered the scene. On board. 				
		(Hi) What effects might trapping fox have on the Indians? 1. decrease population of wild grain 2. increase population of rabbits, field mice	(Lo) Would trapping fox affect the size of the rabbit population? yes And this would then increase the rabbit population for the Indians and increase the field mice.	praise "no" + reason prompt	neutral "no" probe

St+	St-	Sc+	Sc-	Rc+	Re-
		(Hi) Would trapping fox change the ecosystem itself if <u>all</u> there was in the habitat were these animals? no--the set of relationships would still be the same in the food web	(Lo) Since all the relationships would still be the same if only some fox were trapped but not taken out of the food web completely, would the ecosystem still be the same? yes	praise "no" + reason prompt	neutral "no" probe
		(Lo) What if all the fox were trapped so there were no more fox in the food web. Since one of the relationships drops out, would the ecosystem change now? yes (You can circle or (out) squiggle through the relation that drops out)	(Lo) What if all the fox were trapped so there were no more fox in the food web. Since one of the relationships drops out, would the ecosystem change now? yes (You can circle or (out) squiggle through the relation that drops out)	praise "no" + reason prompt	neutral "no" probe
Another possibility if the fox were removed completely is that the Indians might begin to kill more deer for food to replace some of the food lost when more field mice ate more wild grain.	Another possibility if the fox were removed completely is that the Indians might begin to kill more deer for food to replace some of the food lost when more field mice ate more wild grain.				

425

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Hi) Are these kinds of changes in the food web natural--like the Indians killing more deer for food when another population in the community, wild grain, became less available? Why? yes--they represent the way nature would try to balance out the interdependencies in the community	(Lo) The Indians killing more deer is nature's way of trying to balance out the change in one population in the community. So does the Indians' reaction to lower wild grain supply seem natural? yes	praise "no" + reason prompt	neutral "no" probe
This shows that maybe human actions on the environment are perfectly OK from the viewpoint of how nature would balance things out in a community where a population changed for some reason.	This shows that maybe human actions on the environment are perfectly OK from the viewpoint of how ecological balance could be maintained in a community where a population changed for some reason.				
Let's look more closely at the trappers as part of the set of ecological relations					

St+	St-	Sc+	Sc-	Rc+	Rc-
		(Hi) Can the trappers' action of killing fox and beaver be considered to be like a predator-prey relationship? How? yes--the trapper kills fox and beaver for money to buy food, so the fox and beaver are preyed on for food--there's a middle step involved, though. On board: fox → money → food	(Lo) We can picture the trappers' reason for killing fox and beaver like this: On board: fox → money → food So the trapper does prey on the fox for food, only there's an intermediate or middle step involved. Is this like a predator-prey relationship? yes	praise "no" + reason prompt	neutral "no" probe
		(Hi) So is the trappers' killing the fox and beaver kind of like the horned owl who kills field mice? How? yes--both are predator-prey relationships for food	(Lo) The horned owl kills field mice for prey. The trapper kills fox and beaver for prey. Are both examples of predator-prey relationships? yes	praise "no" + reason prompt	neutral "no" probe
			(Lo) Is the only difference between the fox-trapper relationship and the field mice-horned owl relationship that the trapper could use something else for food since it's indirect relation? yes	praise "no" + reason prompt	neutral "no" probe

427

St+	St-	Sc+	Sc-
So the important point we're working up to is that humans can make a conscious decision (on board) about what they want to do in the environment. The trapper could eat rabbits instead of killing fox for money to buy other food.	Humans can decide about what they want to do in the environment. The trapper could eat rabbits instead of killing fox for money to buy other food.		
Let's jump ahead in time to when the factories started dumping wastes and the sewage was put into Peaceful Lake.			

St+	St-	Sc+	Sc-	Rc+	Re-
We've seen that sometimes the things humans do can be considered natural because they are reasonable ways that a population could react to changes in the other populations in its community. Or they might be reasonable changes in response to a change in the set of ecological relationships or the ecosystem.					
		(Hi) All populations, including humans, have wastes. Since none of the other populations try to chemically treat their waste materials why do humans treat theirs? ...focus on answers with reasons from prior material that accurately support students' conclusions (Hi) what do you think? ...redirect about 4 times	(Hi) All populations, including humans, have wastes. Since none of the other populations try to chemically treat their waste materials, why do humans treat theirs? ...focus on answers with reasons from prior material that accurately support students' conclusions	praise "no" + reason prompt On board	neutral "no" probe

429

St+	St-	Sc+	Sc-	Rc+	Rc-
So there are several possibilities. Suppose we take the position for now that dumping sewage is no different from the way other animal and plant populations live and enter into relationships in an ecosystem.	Suppose we take the position for now that dumping sewage is no different from the way other animal and plant populations live in ecosystems.				
		(Hi) Since we are assuming for now that this is a natural thing to do ecologically, would the plan to chemically treat waste materials from human populations be ecologically unsound or unnatural? Why? ...focus on process in answers from prior materials	(Lo) For the sake of argument, we're assuming that dumping waste materials is just like other ecologically sound actions by other animal and plant populations. Would the plan to chemically treat wastes be unsound ecologically? Why? ...focus on process answers from prior materials	praise process "no" + reason prompt	neutral "no" probe

430

605 606

St+	St-	Sc+	Sc-	Re+	Re-
We could argue these points back and forth for a long time. But remember that humans have the ability to <u>decide</u> what to do about changing the relationships that make up an ecosystem. That's the <u>important difference</u> between the human population and other populations of plants and animals. Since humans can decide, let's try to look at reasons that could help us to choose between good decisions and bad decisions about how to change an ecosystem or a community.					
		(Hi) Are major changes in the environment quick to happen or do they take a long time? What are examples? both—forest fires are quick, ecological succession takes a long time	(Lo) How long does it take for a forest fire to change an environment? only a short time	praise "no" + reason prompt On board	neutral "no" probe
			(Lo) How about ecological succession? a long time	praise "no" + reason prompt	neutral "no" probe

431

St+	St-	Sc+	Sc-	Rc+	Rc-
Environmental changes in communities and ecosystems occur often--some are very short, like a forest fire. Others take a very long time, like ecological succession.	Environmental changes in communities and ecosystems occur often--some are very short, like a forest fire. Others take a very long time, like ecological succession.				
			(Lo) Is a forest fire bad for maple trees? Why? yes--it decreases the population	praise "no" + reason prompt	neutral "no" probe

432

609 610

St+	St-	Sc+	Sc-	Re+	Re-
			(Lo) How about for the space they clear for low growing shrubs, grasses, and other populations that move in after a forest fire? the fire's good for them	praise "no" + reason prompt On board	neutral "no" probe
			And since we're all creatures of nature, forest fires caused by lightning and sewage dumped by humans bring about natural changes in the ecosystem relationships.		
So the answer to whether changes in the ecosystem relationships are good or bad depends on which population you're considering to be affected by the change. That's a very important point--the value of a change is relative to which population. This is called the relative value of change. (On board)	So the answer to whether changes in the ecosystem relationships are good or bad depends on which population you're considering to be affected by the change. This is called the relative value of change.				

433

St+	St-	Sc+	Sc-	Rc+	Rc-
Remember we said that some changes in ecosystems and communities take a very short time while others take a very long time. Since humans can decide to change an ecosystem in different ways that have different effects, one aspect of this choice should be <u>how quickly the change should occur</u>. On board	Humans' decisions to change ecosystems can have effects that occur very quickly or that take a long time to have an effect. So one aspect of the choice to change an ecosystem should be how quickly the change should occur.				
		(Hi) Are immediate effects or delayed effects of a change the same? For example, spraying pesticides on grains increases the population of grains and gives us more food. That's the immediate effect. After a longer time, we build up harmful poisons in our bodies. That's a long term or delayed effect.	(Lo) Would changes in our use of pesticides to kill grain eating insects have immediate effects on the populations of grains? yes--they help grains to survive	praise "no" + reason prompt On board	neutral "no" probe
			(Hi) Do they also have long range effects on human populations? How? yes--we build up harmful poisons in our bodies over long periods of times as we eat the extra grain available	praise "no" + reason prompt On board	neutral "no" probe

434

St+	St-	Sc+	Sc-
So another point to think about in our decisions to change the environment is how quickly a change affects different populations. Spraying pesticides has an immediately helpful effect on the populations of grains and humans. It has a harmful delayed effect on the human population, however, as the poisons in the pesticides build up in our bodies. This very important idea can be called the relative time for an effect. On board: relative time for an effect	So another point to think about in our decisions to change the environment is how quickly a change affects different populations. This can be called the relative time for an effect.		
There are other points to consider in choosing among decisions about how humans should influence the environment. These are too complicated for us to consider. I invite you to think about them on your own.			

St+	St-	Sc+
OK, let's review what we covered today: 1. We reviewed many of the key ideas in the science of ecology: a. definition of ecology b. what a relationship is c. role of energy in ecosystems d. populations and factors affecting them e. communities f. the idea of ecosystems 2. The idea of changes in ecosystems and the ripple effect. 3. Criteria for good vs. bad changes that humans make in ecosystems are relative: a. to which populations are affected b. to the time it takes for populations to be affected 4. Humans are set apart by their ability to choose between different decisions		

APPENDIX C

OF

A FACTORIALLY DESIGNED EXPERIMENT ON

TEACHER STRUCTURING, SOLICITING, AND REACTING

November 1976

TESTS OF STUDENT APTITUDE, ACHIEVEMENT, ATTITUDE, AND PERCEPTIONS OF TEACHER BEHAVIOR

Program on Teaching Effectiveness
Stanford Center for Research and Development in Teaching

TESTS OF STUDENT APTITUDE, ACHIEVEMENT, ATTITUDE, AND PERCEPTIONS OF TEACHER BEHAVIOR

CONTENTS

Stanford University
School of Education
Stanford Center for Research and Development in Teaching
Program on Teaching Effectiveness

Recitation Study

Winter-Spring 1975

Questionnaires and Tests

PRETESTS

NAME____

Please give us the following information about yourself:

girl or boy ____________________

age ________ birthday ______________________________________

grade ________ school ____

regular teacher's name ____

are you right handed? _______________

" " left handed? _______________

How well do you like tests? Check the blank below that comes closest to telling how you feel about taking them.

Don't like at all	Don't like them much	They're OK	I like to take tests	I really like taking tests
________	________	______	________	________

PLEASE DO NOT BEGIN UNTIL ASKED TO DO SO

WORD LIST TEST

This is a test of your ability to remember a list of words. When I tell you to, turn the page and study the list of words there. You will have 2 minutes to study. When I say so, turn the page and write all the words you can remember.

DO NOT turn back to the original list of words. You will have 2 minutes to write all the words you remember.

Ready?

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

Study this list. You will have 2 minutes.

banana

rug

history

bear

spelling

grape

biology

pear

beaver

pineapple

art

lamp

dog

table

geography

goat

couch

peach

camel

bookcase

chemistry

desk

melon

deer

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

[This page was inserted to prevent students from being able to read through the reverse side of the preceding page while responding to the test.]

Write all the words you can remember. You will have 2 minutes.

DO NOT turn back to the original list.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

TF? STATEMENTS ABOUT ECOLOGY

On the next page are statements like the following:

T F ? Water is wet.

T F ? Sequoia sempervirens is the species name for longneedle pine trees.

When you know the answer to a question, cross out the T if the statement is true, or the F is the statement is false. Since water is wet, you would cross out the T like this: ~~T~~. When you are not certain that the statement is true or false, cross out the question mark. You probably don't know whether the second statement is true or false, so you would cross out the question mark like this: ~~?~~.

There are 20 statements like this on the next page. Read each statement carefully and mark your answer by crossing out T, F, or ? . DO NOT cross out more than one choice. It will NOT be to your advantage to guess. Do not mark T or F unless you are almost completely certain the statement is true or false.

Ready?

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

T F ? Ecology is a science because it doesn't try to make general statements about things in nature.

T F ? Climate is an important factor in ecology.

T F ? Useful energy in the form of heat can be transferred from one living thing to another.

T F ? Materials like carbon and nitrogen get used up by living things.

T F ? A pine forest is a succession community.

T F ? A food chain is a path for the flow of energy in the environment.

T F ? Pine trees, oak trees, and cherry trees all belong to the same population of living things.

T F ? Energy stored in organic materials is one form of potential energy.

T F ? Competition is a large influence on the size of a population of living things.

T F ? Abandoned woodchuck holes are the habitat of many snakes.

T F ? A growth curve for a population would show that the number of living things in the population increases very rapidly at first.

T F ? Kinetic energy is seen in activities like running or breathing.

T F ? Biomes are usually named after famous people or the person who discovered them.

T F ? Bees and flowers take part in an ecological relationship called a competitive relationship.

T F ? There are both long cycles and short cycles for water in the environment.

T F ? A food web describes how materials and energy move through different parts of the environment.

T F ? Animal wastes are useless in nature.

T F ? The basic source of all energy in the environment is the sun.

T F ? Forest fires are good for some living things.

T F ? Almost all the energy in plants eventually gets used by humans.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

ATTITUDE TOWARD ECOLOGY

We also want to know how interested people are about various things in ecology. On the following two pages are statements like these:

I don't like warm sunny days.

______	______	______	______	______
Strongly Agree	Agree	Don't Care	Disagree	Strongly Disagree

I am interested in the science of weather.

______	______	______	______	______
Strongly Agree	Agree	Don't Care	Disagree	Strongly Disagree

Please check the answer that tells best how much you agree or disagree with each statement about yourself. For example, if you <u>really</u> like warm sunny days, you'd put a (✓) on the line above strongly disagree. If you don't really care to learn about the science of weather, you'd put a check (✓) on the line above don't care.

There are no right or wrong answers for these exercises. They simply tell how you feel.

Ready?

<u>DO</u> <u>NOT</u> TURN THIS PAGE UNTIL ASKED TO DO SO

1. It's interesting to me to know how living things depend on each other in nature.

Strongly Agree   Agree   Don't Care   Disagree   Strongly Disagree

2. I probably wouldn't like to study about ecology because it's about science.

Strongly Agree   Agree   Don't Care   Disagree   Strongly Disagree

3. I wouldn't be interested in spending time and energy to recycle aluminum cans and paper.

Strongly Agree   Agree   Don't Care   Disagree   Strongly Disagree

4. I'd like to learn about things like why birds migrate or why bears hibernate.

Strongly Agree   Agree   Don't Care   Disagree   Strongly Disagree

5. Ecology doesn't interest me very much.

Strongly Agree   Agree   Don't Care   Disagree   Strongly Disagree

6. I'd be bored going on a hike with someone who explained things about the plants and animals we saw.

Strongly Agree   Agree   Don't Care   Disagree   Strongly Disagree

7. If ecology weren't taught in school, I probably wouldn't want to learn much about it.

Strongly Agree   Agree   Don't Care   Disagree   Strongly Disagree

8. I'd like to learn about the science of ecology.

Strongly Agree   Agree   Don't Care   Disagree   Strongly Disagree

GO ON TO THE NEXT PAGE IMMEDIATELY

9. If a friend told me about a magazine article on how our changing climate was affecting the environment, I'd probably read it.

Strongly Agree	Agree	Don't Care	Disagree	Strongly Disagree

10. I wish there were more programs on TV about ecology.

Strongly Agree	Agree	Don't Care	Disagree	Strongly Disagree

11. I'd enjoy learning about how the plants and insects in a terrarium (a little garden in a bottle) can stay alive in such a small space.

Strongly Agree	Agree	Don't Care	Disagree	Strongly Disagree

12. I'd rather learn about tennis or how the Egyptians built the pyramids than learn about ecology.

Strongly Agree	Agree	Don't Care	Disagree	Strongly Disagree

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

GROUPS OF WORDS TEST

People usually find it helpful to group words into categories that make sense when they are trying to remember a list of words. Look at the examples below.

mountain

diamond

river

emerald

ruby

stream

These words can be put into 2 groups--geographical features and gems--like this:

mountain	diamond
river	ruby
stream	emerald

When I tell you to, turn the page and study the list of words there. You will have 2 minutes to study. When I say so, turn the page and write the words you remember in groups like in the example.

DO NOT turn back to the original list of words. You will have 2 minutes to write all the words you remember.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

Study this list. <u>Remember to put words into groups</u>. You will have 2 minutes

toe

brass

beet

copper

elbow

steel

corn

ankle

moth

ear

silver

pea

head

roach

cabbage

tin

flea

bean

fly

potato

hornet

iron

cricket

knee

<u>DO</u> <u>NOT</u> TURN THIS PAGE UNTIL ASKED TO DO SO.

[This page was inserted to prevent students from being able to read through the reverse side of the preceding page while responding to the test.]

Write all the words you can remember. Be sure to put them in groups. You will have 2 minutes. DO NOT turn back to the original list.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

A CHECKLIST ABOUT WHAT HELPS YOU LEARN

Some students learn best when a teacher teaches in one way, while other students learn best when a teacher teaches in a different way. Think about how much you learn from a teacher who:

How much do you learn?

	Not at all	Less than usual	About the same as usual	More than usual	A lot more than usual
Uses the chalkboard a lot	______	______	______	______	______

If the teacher using the chalkboard doesn't help you learn at all, put a check (✓) under "Not at all." If the teacher using the chalkboard helps you learn more than usual, put a check (✓) under "More than usual."

There are 15 statements like this on the next page. For each statement, make one check that describes best how well you think that kind of teaching will help you learn.

Ready?

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

How much do you think you learn from each of these things that teachers might do?

	Not at all	Less than usual	About the same as usual	More than usual	A lot more than usual
1. Tells me what is really important to learn	___	___	___	___	___
2. Asks questions only about things I've read	___	___	___	___	___
3. Gives the answer when students don't answer questions correctly	___	___	___	___	___
4. Goes over important things at the end of each day's lesson	___	___	___	___	___
5. Waits a little while before letting me answer questions	___	___	___	___	___
6. Tells us why wrong answers are wrong	___	___	___	___	___
7. Doesn't tell me exactly what I'm supposed to learn	___	___	___	___	___
8. Asks other students to answer the same question	___	___	___	___	___
9. Says nothing besides "no" when I give a wrong answer	___	___	___	___	___
10. Ties together ideas during the lesson	___	___	___	___	___
11. Gives me a hint when the answer to a question isn't exactly right	___	___	___	___	___
12. Says things like "Great!" when I answer questions correctly	___	___	___	___	___
13. Keeps me guessing about what we're going to talk about next	___	___	___	___	___
14. Asks questions that really make me think	___	___	___	___	___
15. Emphasizes the reasoning used in answering questions	___	___	___	___	___

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

OBJECT-NUMBER TEST

This is a test of your ability to learn pairs of words and numbers. On one page, you will study 15 names of objects with numbers. After studying the pairs of objects and numbers for 3 minutes, you will turn to a new page showing the names of the objects in a different order. You will have 2 minutes to write down the numbers that go with them.

Here is a practice list. Study it until you are asked to turn to the practice test page.

Object	Number
window	73
desk	41
carpet	19
door	84
glass	90

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

PRACTICE TEST PAGE

For the first object below, the correct number has been written. Write all of the other numbers that you can remember.

Object	Number
desk	41
glass	______
window	______
door	______
carpet	______

If you aren't sure of the correct number for an object, make your best guess. Try your best. DO NOT turn back to the original list.

Ready?

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

Study this list. You will have 3 minutes.

Object	Number
tree	58
floor	29
chair	33
wall	56
shoe	17
table	78
coat	49
roof	22
dish	36
pillow	43
post	65
tile	35
plate	26
shade	40
rock	62

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

[This page was inserted to prevent students from being able to read through the reverse side of the preceding page while responding to the test.]

Write the number that belongs with each object. You will have 2 minutes. DO NOT turn back to the original list.

Object	Number
coat	______
post	______
pillow	______
floor	______
shoe	______
shade	______
tile	______
roof	______
wall	______
rock	______
tree	______
chair	______
plate	______
dish	______
table	______

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

WORD PAIRS TEST

This is a test of your ability to learn pairs of words. You will study 15 pairs of words like those below.

ring	telephone
spoon	nail
button	lip

After studying the page showing the pairs of words, you will turn to a page showing the first word of each pair in a different order from the list you studied. You will be asked to write the words that go together from the word you are given. Look at the example. For "spoon" you would write "nail".

spoon	nail
ring	______
button	______

People often find it easier to remember the pairs of words that go together by making up a little sentence that uses both words in the pair. For example, you might say, "A ring means answer the telephone." When you see the word "ring", you could repeat the sentence to remember the word that goes with ring.

Other people find it better to make a picture in their mind that relates the two words. For example, you might remember the pair "button" and "lip" by imagining a picture of lips buttoned together to write the word that goes with "button".

Here is a practice list. Try out the different ways of remembering--simply memorizing, using a sentence, or making a mental picture--to see which is best for you.

ruler	rabbit
clock	book
daisy	cup

When I tell you to, turn the page and study the pairs of words. Then, when I say so, turn the page and write the word that goes with the words you are given. DO NOT turn back to the original list of words. You will have 2 minutes to study and 2 more minutes to write all the words you can remember.

Ready?

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

Study the pairs of words. You will have 2 minutes.

bridge	grass
tank	bun
mountain	key
door	tree
wood	newspaper
snake	brain
oil	fork
pencil	mirror
rainbow	smoke
magnet	water
tongue	pony
car	sun
shoelace	river
crayon	penny
jet	elephant

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

[This page was inserted to prevent students from being able to read through the reverse side of the preceding page while responding to the test.]

Write the word that goes with the word you are given

magnet	______
oil	______
rainbow	______
tank	______
door	______
pencil	______
bridge	______
shoelace	______
tongue	______
mountain	______
jet	______
snake	______
wood	______
car	______
crayon	______

<u>DO</u> <u>NOT</u> TURN THIS PAGE UNTIL ASKED TO DO SO.

How did you remember the pairs of words? Circle how much you used each way.

	Didn't use this way	Used this way sometimes	Used this way a lot	Used only way only
How much did you use plain memorizing?	1	2	3	4
How much did you use sentences with both words?	1	2	3	4
How much did you use mental pictures?	1	2	3	4
How much did you use some other way?	1	2	3	4

What was this other way? ______________________________

Stanford University
School of Education
Stanford Center for Research and Development in Teaching
Program on Teaching Effectiveness

Recitation Study

Winter-Spring 1975

Questionnaires and Tests

POSTTESTS

NAME ______________________________

Girl________ Boy________

Birthday________/______/______
Month / Day / Year

Name of your school____

TEACHER CHARACTERISTICS SCALE

Check how often YOUR ECOLOGY TEACHER acts like this when teaching the ecology lessons.

	Almost never	Not very often	Sometimes	A lot	Almost always
1. Seems like she doesn't like teaching	___	___	___	___	___
2. Seems unsure about parts of the lesson	___	___	___	___	___
3. Is a nice person	___	___	___	___	___
4. Lets students fool around	___	___	___	___	___
5. Really knows the material in each lesson	___	___	___	___	___
6. Seems unfriendly	___	___	___	___	___
7. Teaches in a disorganized way	___	___	___	___	___
8. Presents ideas so I can understand them	___	___	___	___	___
9. Teaches with lots of enthusiasm	___	___	___	___	___
10. Doesn't explain things clearly	___	___	___	___	___
11. Presents material in an orderly way	___	___	___	___	___
12. Keeps the class paying attention to the lesson	___	___	___	___	___

GO ON TO NEXT PAGE IMMEDIATELY

TREATMENT ATTRIBUTE SCALE

	Almost never	Not very often	Sometimes	A lot	Almost always
13. Tells me what is really important to learn	____	____	____	____	____
14. Asks questions only about things I've read	____	____	____	____	____
15. Gives the answer when students don't answer questions correctly	____	____	____	____	____
16. Goes over important things at the end of each day's lesson	____	____	____	____	____
17. Waits a little while before letting me answer questions	____	____	____	____	____
18. Tells us why wrong answers are wrong	____	____	____	____	____
19. Doesn't tell me exactly what I'm supposed to learn	____	____	____	____	____
20. Asks other students to answer the same question	____	____	____	____	____
21. Says nothing besides "no" when I give a wrong answer	____	____	____	____	____
22. Ties together ideas during the lesson	____	____	____	____	____
23. Gives me a hint when the answer to a question isn't exactly right	____	____	____	____	____
24. Says things like "Great!" when I answer questions correctly	____	____	____	____	____
25. Keeps me guessing about what we're going to talk about next	____	____	____	____	____
26. Asks questions that really make me think	____	____	____	____	____
27. Emphasizes the reasoning used in answering questions	____	____	____		

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

Please answer each of the three essay questions in the space provided. You will have 15 minutes for all three questions. So allow yourself about five minutes for each question.

1. How is a food chain similar to a food web? What relation do food chains and food webs have to the concept of an ecological community?

2. Whales eat tiny organisms called plankton. Plankton are both animals and green plants. Humans used to kill whales for whale oil that was used to light their homes. Draw and label a diagram to describe the flow of energy in this example and illustrate how the principle of conservation of energy applies to this energy flow.

(Diagram here)

GO ON TO THE NEXT PAGE IMMEDIATELY

3. A farmer bought a piece of dry desert-like land that occupies about 50 square miles. Currently, the land has good soil but not enough water to grow anything but cactus and a little grass. The farmer will build irrigation ditches to get enough water to the land so he can grow big apple trees. Compare the matter cycles and energy flow in this community to those of the old community before the irrigation ditches were dug.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

On the line below, place an X in one of the ten spaces that best describes what percent of the questions you think you will answer correctly on the multiple-choice achievement test you are about to take.

____:	____:	____:	____:	____:	____:	____:	____:	____:	____:
10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

How well I expect to do on the multiple-choice achievement test.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

Choose the best answer and put its number in the space to the left. Because you will have only 20 minutes, please do not spend too much time on any single question. If you have no idea of what the answer should be, do not guess but go on to the next question.

______ 1. The science of ecology mainly explores the

1) nature of living things.
2) relationships between living and non-living things.
3) problems of pollution and overpopulation.
4) ways to conserve energy.

______ 2. What process do living things use to turn potential energy into kinetic energy?

1) Breathing
2) Photosynthesis
3) Recycling
4) Oxidation

______ 3. A large geographical region composed of roughly the same kinds of habitats and having the same general kinds of ecological relationships is called

1) a population.
2) a community.
3) an ecological succession.
4) a biome.

______ 4. The energy producers in all food chains are

1) bacteria.
2) small scavengers.
3) animals that contain chlorophyll.
4) green plants.

______ 5. When an organism is young and growing, it builds new body parts. What is needed to bind materials together to form the new parts?

1) Energy
2) Matter
3) Organic glue
4) Oxidation

______ 6. If a living organism were able to make its own food, it would be called a

1) decomposer.
2) 1st order consumer.
3) producer.
4) prey.

GO ON TO THE NEXT PAGE IMMEDIATELY

_____ 7. What was the major factor limiting the size of the population of Columbian black-tailed deer on Angel Island?

1) Starvation
2) Predation by wolves
3) A decrease in litter size
4) A decrease in mortality

_____ 8. Energy that flows in the ecosystem moves in a very important way. This energy moves from

1) consumers to producers.
2) plants to the atmosphere.
3) decomposers to the environment.
4) producers to consumers.

_____ 9. What do decomposers do in the ecosystem?

1) They return energy to the environment for use by the producers.
2) They release matter from dead organisms for use by other organisms.
3) They use heat in the environment.
4) They decrease the mineral supply in the environment.

_____ 10. A complex relationship involving many plants and animals that feed on each other is called a

1) food chain.
2) food habitat.
3) food web.
4) feeding relationship.

_____ 11. A ripple effect in ecology is said to occur when

1) changes in one population influence changes in other populations.
2) heat is lost from use.
3) water cycles through many living things in the environment before evaporating.
4) relatively long lasting conditions in the environment change back to their original conditions.

_____ 12. Which of the following organisms are the producers in the nitrogen cycle?

1) Green plants
2) Bacteria
3) Fungi
4) Earthworms

GO ON TO THE NEXT PAGE IMMEDIATELY

______13. The specific area in which a particular population lives is called its

1) ecosystem.
2) environment.
3) community.
4) habitat.

______14. A collection of populations that depend on each other and live in the same area is called a

1) community.
2) population.
3) food web.
4) habitat.

______15. The climate of an ecosystem has two basic parts. What are these two parts?

1) Soil type, temperature
2) Moisture, temperature
3) Soil type, moisture
4) Altitude, temperature

______16. What was one way humans made up for the inability of natural matter cycles to support them at Peaceful Lake?

1) Dumping sewage into the lake
2) Clearing trees for farmland
3) Using fertilizers
4) Making dumps

______17. A group of one kind of living organism that lives in the same area is called

1) an ecosystem.
2) a population.
3) a community.
4) a food web.

______18. Which of the following is the best example of a system?

1) A combined relationship
2) Animals eating plants
3) A predator-prey relationship
4) A simple relationship

GO ON TO THE NEXT PAGE IMMEDIATELY

_____19. In Peaceful Lake, large globs of floating algae would stop sunlight from reaching many small water plants that some fish used as a source of food. This would have a large effect on

1) the role of decomposers in the ecosystem of Peaceful Lake.
2) matter cycles for water and carbon.
3) predator-prey relationships between frogs and insects.
4) energy flow from producers to consumers.

_____20. Suppose a blueberry bush used sunlight to make food for itself, and stored the food in its blueberries. Now a robin flies up and lands on the bush and eats the blueberries. The robin would be an example of a

1) producer.
2) consumer.
3) decomposer.
4) predator.

_____21. There are black squirrels and grey squirrels in the Palo Alto area. They live in the same trees and eat the same food. This is an example of what kind of relationship?

1) Predator prey
2) Mutual benefit
3) Competitive
4) Benefit-no difference

_____22. A decrease in the amount of food available for humans could be caused by increasing the

1) production by producers.
2) efficiency of energy used by herbivores eaten by humans.
3) number of consumer levels between producers and humans.
4) use of chemical fertilizers.

_____23. When builders were planning the construction of the four foot tall Alaskan pipeline that goes from the northern to the southern part of Alaska, ecologists argued that this would be destructive to the Caribou (Elk). What adaptive behavior of the Caribou would the pipeline affect?

1) Evolution
2) Hibernation
3) Pollution
4) Migration

_____24. At each step in the energy flow, we find smaller and smaller amounts of

1) useful energy.
2) kinetic energy.
3) heat.
4) energy stored by photosynthesis.

GO ON TO THE NEXT PAGE IMMEDIATELY

_____25. Humans can change an ecosystem by building a dam to trap water so electricity can be generated when the water is slowly released. Is this an unnatural or unecological action?

1) Yes
2) No
3) It depends on whether you consider short-term or long-term changes in the ecosystem.
4) It depends on whether the dam makes any changes in the ecosystem.

_____26. Which of the following is a good example of an ecological community?

1) Whales, frogs, lizards, and seaweed
2) Deer, berry bushes, wolves, and bacteria
3) Moss, cactus, rabbits, and salmon
4) Pine trees, salamanders, spiders, and porpoises

_____27. The sugar found in sugar cane has been produced by a process of

1) photosynthesis.
2) chlorophyll.
3) oxidation.
4) energy transfer.

_____28. When whales eat microscopic animals, they are participating in a

1) good-bad relationship.
2) mutual benefit relationship.
3) benefit-no difference relationship.
4) predator-prey relationship.

_____29. If carbon dioxide were withdrawn from the atmosphere, which kind of organism would experience problems first?

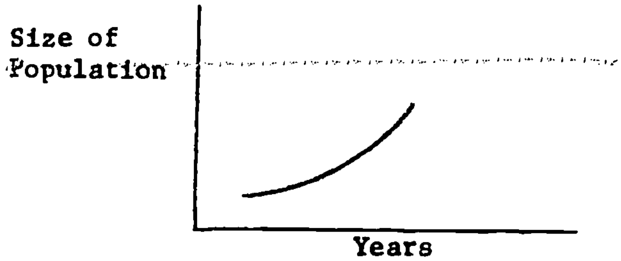
1) First order consumers
2) Second order consumers
3) Producers
4) Decomposers

_____30. Carbon is made available to most consumers by

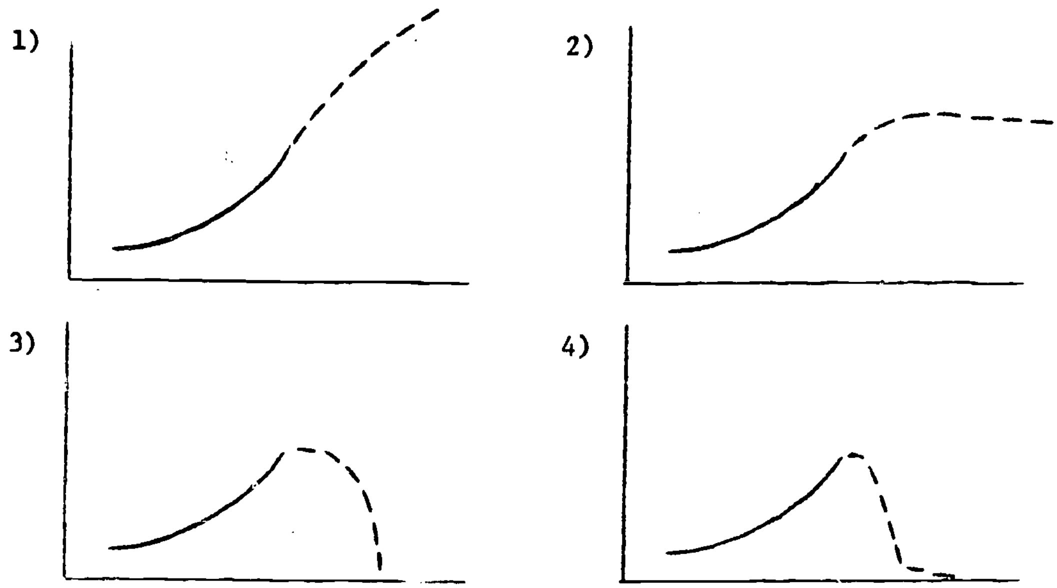
1) the activities of decomposers.
2) the activities of green plants.
3) rain falling through the atmosphere.
4) upheavals in the earth's crust.

GO ON TO THE NEXT PAGE IMMEDIATELY

31. This graph shows how the size of the population of brown salamanders has been changing over the last several years:



Which graph in dotted lines shows how the population probably will change in the next few years?



______32. What would be the name of a community that consists of white-pine trees, hawks, rabbits, mice, sparrows, insects, bacteria, and mushrooms?

1) A rabbit community
2) A hawk community
3) A white-pine tree community
4) A mushroom community

______33. Through which of the following does the greatest amount of energy flow?

1) Producers
2) 1st-order consumers
3) 2nd-order consumers
4) Decomposers

GO ON TO THE NEXT PAGE IMMEDIATELY

_____34. A brown bear eats berries, field mice, honey, and fish. The best description of a brown bear is a

1) herbivore.
2) decomposer.
3) multi-level consumer.
4) scavenger.

_____35. The best evidence that a population is surviving in a particular environment is its

1) rapid rate of mutation.
2) increasing size of habitat.
3) position in the food chain.
4) successful reproduction.

_____36. A bird eats sunflower seeds from a garden. Later, a cat eats the bird. These events make up

1) a food chain.
2) a predator-prey relationship.
3) an ecosystem.
4) a biome.

Stanford University
School of Education
Stanford Center for Research and Development in Teaching
Program on Teaching Effectiveness

Recitation Study

Winter-Spring 1975

Questionnaires and Tests

ANSWER KEYS AND SUBSCALES

Word Meaning Test (Vocabulary)

Answer Key

Item	Correct Answer	Item	Correct Answer
1	5	19	1
2	1	20	4
3	3	21	2
4	2	22	2
5	5	23	3
6	1	24	4
7	3	25	1
8	5	26	5
9	2	27	5
10	5	28	3
11	3	29	1
12	4	30	4
13	2	31	4
14	5	32	5
15	3	33	1
16	2	34	2
17	3	35	3
18	4		

T-F-? Statements About Ecology

Answer Key

Item	Correct Answer
1	False
2	True
3	False
4	False
5	True
6	True
7	False
8	True
9	True
10	True
11	False
12	True
13	False
14	False
15	True
16	True
17	False
18	True
19	True
20	False

("?" responses are scored as incorrect.)

Attitude Toward Ecology

Items on which the scale is reversed for scoring purposes

1

4

8

9

10

11

A Checklist About What Helps You Learn

Subscales

	Subscale		
	Structuring	Soliciting	Reacting
Items	1	2*	3
	4	5	6
	7*	14	8
	10		9*
	13*		11
			12
			15

*Scale reversed for scoring purposes.

Teacher Characteristics Scale

Subscales

	Subscale					
	Enthusiasm	Knowledge	Warmth	Management	Organization	Clarity
Items	1,9	2,5	3,6	4,12	7,11	8,10

Treatment Attribute Scale

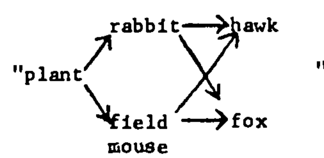
Subscales

	Subscale		
	Structuring	Soliciting	Reacting
Items	13	14*	15
	16	17	18
	19*	26	20
	22		21*
	25*		23
			24
			25

*Scale reversed for scoring purposes

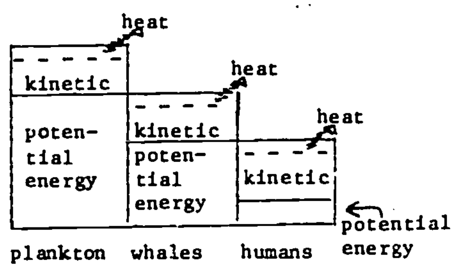
Essay Test: Model Answers

How is a food chain similar to a food web? What relation do food chains and food webs have to the concept of an ecological community?

Concept	1-point answer	2-point answer
Path for the flow of energy	"Both involve energy." "Energy keeps both working."	"A food chain and a food web are pictures of how energy moves in an ecosystem." "Both show the things that energy flows through and the order that energy flows through them."
A part of the matter cycle	"Matter goes through them."	"These two things show how matter, like carbon, is moved during part of its cycle." "Food chains and food webs picture the animals and plants that matter flow through as it goes through the ecosystem."
Consumers and producers	"Both food chains and food webs have consumers." "There's always a plant in both of these."	"Food chains and food webs both have producers, like plants or nitrogen-fixing bacteria, and consumers, like rabbits." "They both start with producers and then tie together consumers."
Example of food chain	"A food chain might include a rabbit, a hawk, and a plant."	"plant→rabbit→hawk" "A rabbit might eat a plant, then a hawk might eat the rabbit. This is a food chain."
Example of food web	"A food web might include a rabbit, a hawk, a plant, a fox, and a field mouse."	 "A rabbit and a field mouse both eat plants. A fox can eat both of these and so can a hawk."
Relation to ecological community	"They show how things in an ecological community eat each other."	"Food chains and food webs show how plants and animals are interdependent and this is a part of the definition of a community." "You can guess what will happen if part of the food chain or food web changed.

Concept	1-point answer	2-point answer
Relation of food chain to food web	"One is made up of the other." "Food webs are more complicated."	"A food web is made up of several food chains linked together. "A food web consists of food chains where one animal is in two food chains so they are connected together."

Whales eat tiny organisms called plankton. Plankton are both animals and green plants. Humans used to kill whales for whale oil used to light their homes. Draw and label a diagram to describe the flow of energy in this example and illustrate how the principle of conservation of energy applies to this flow.

Concept	1-point answer	2-point answer
Diagram of energy flow	plankton → whales → humans heat heat heat Note: diagram without an indication of heat loss receives zero points.	 Note: diagram without indication of heat loss receives one point.
Principle of conservation of energy	"Adding up all the energy used plus the energy left equals the energy in the beginning." "The amount of energy to start with always stays the same but gets changed to different kinds of energy."	"If you add up all the heat lost plus all the kinetic energy used plus whatever potential energy left at a place in the energy flow, you'll have the total amount of energy the producer (plant, plankton) started with."
Applying the principle to this diagram	"All the potential energy plus all the heat given off plus the kinetic energy equals the original energy in the plankton."	"The potential energy left after the oil was burned, plus the heat and kinetic energy used in the oil, plus the heat given off and the kinetic energy used by the whale, plus the heat given off and the kinetic energy used by the plankton equals all the energy the plankton had originally." "All the heat given off plus the kinetic energy used plus the potential energy left at the end equals the energy the plankton had to start with."

A farmer bought a piece of dry desert-like land that occupies about 50 square miles. Currently, the land has good soil but not enough water to grow anything but cactus and a little grass. The farmer will build irrigation ditches to get enough water to the land so he can grow big apple trees. Compare the matter cycles and energy flow in the community to those of the old community before the irrigation ditches were dug.

Concept	1-point answer	2-point answer
Matter cycles before irrigation	"The matter cycles would be shorter before irrigation began." "The nitrogen cycle will be simple."	"The matter cycles would be short because there wouldn't be many consumers." "The matter cycles wouldn't be very complex because they would involve maybe only a producer and one or two consumers."
Matter cycles afer irrigation	"The matter cycles would get longer." "There would be more consumers in the matter cycles."	"More water would help more consumers to live so the matter cycles would get more complicated because there would be more things for the matter to go through." "Water would mean that food chains and food webs could get bigger and have different animals in them. The matter cycles would change because of these changes in the food webs."
Comparison of before and after matter cycles	"The matter cycles would be different sizes." "Matter cycles would be generally the same though."	"The changes would be that there would be more members in the matter cycle, but the general idea of a matter cycle would be the same."
Energy flow before irrigation	"The energy would not move very far." "There wouldn't be a long energy flow."	"There would only be a producer and maybe one consumer in the energy flow because there wouldn't be enough water to support more energy consumers." "There would be only 2 or 3 living things in the energy flow because not enough things could live without water to have a longer energy flow."

Concept	1-point answer	2-point answer
Energy flow after irrigation	"The energy flow would take longer." "The producers of energy would be bigger and more influential than before."	"More water would mean more consumers, so the number of steps in the energy flow would get larger." "The greater number of apple trees would mean that more energy would be available in the ecosystem because apple trees are energy producers."
Comparison of before and after energy flow	"The energy flow would still be like other energy flows in general." "The big difference is the greater number of consumers of energy after irrigation."	"The general idea of energy flow would still be unidirectional, only there would be more energy consumers to lengthen the energy flow. There also would be a bigger basis for energy because of more energy producers (the apple trees)."

Multiple-Choice Test

Answer Key

Item	Correct Answer	Item	Correct Answer
1	2	19	4
2	4	20	2
3	4	21	3
4	4	22	3
5	1	23	4
6	3	24	1
7	1	25	3
8	4	26	2
9	2	27	1
10	3	28	4
11	1	29	3
12	2	30	2
13	4	31	2
14	1	32	3
15	2	33	1
16	3	34	3
17	2	35	4
18	1	36	1

Multiple-Choice Test

Subscales

	Subscale			
	Lower Order Text-plus-Teacher	Higher Order Text-plus-Teacher	Lower Order Teacher-Only	Higher Order Teacher-Only
Items	1	19	2	21
	6	20	3	23
	8	22	4	25
	9	24	5	27
	10	26	7	29
	14	28	11	31
	15	30	12	32
	16	35	13	33
	17	36	18	34

Multiple-Choice Test

Items from each lesson

	Lesson								
	1	2	3	4	5	6	7	8	9
Items	1	2	4	9	5	7	13	3	11
	18	6	8	12	10	17	14	15	16
	21	20	24	29	34	31	26	22	19
	28	27	33	30	36	35	32	23	25

APPENDIX D

OF

A FACTORIALLY DESIGNED EXPERIMENT ON

TEACHER STRUCTURING, SOLICITING, AND REACTING

November 1976

AN OBSERVATION SYSTEM TO ASSESS TEACHER
STRUCTURING, SOLICITING, AND REACTING,
AND STUDENT RESPONDING

Program on Teaching Effectiveness

Stanford Center for Research and Development in Teaching

As part of "A Factorially Designed Experiment on Teacher Structuring, Soliciting, and Reacting," Program on Teaching Effectiveness, Stanford Center for Research and Development in Teaching, 1976, an observation instrument was developed to measure the fidelity with which the teaching behaviors were manipulated in this study. The instrument called for the observer to check which one or more categories of events occurred during each 10-second interval of the observation period. A cassette tape was made with signals at 10-second intervals. The coder(s) listened to the signals through headsets connected to the cassette recorder.

Since the purpose of this system was to measure the fidelity of treatment implementation, the system was designed to include only those behaviors manipulated in the experiment. Thus, the categories of events that were checked were the components of teacher structuring, teacher soliciting, student talk or responding, and teacher reacting. In addition, two other categories were added: teacher presenting information and unclassifiable. Teacher presenting information was defined as teacher lecturing or giving new information, i.e., information not previously presented. According to this definition, teacher structuring and teacher presenting information were independent dimensions. Unclassifiable included simultaneous student talk, disruptive remarks, and other events that did not fit into any other category. The other categories are defined in the manual used to train coders which is included in this appendix.

A copy of the observation form appears on the next page. The behaviors observed are listed on the left-hand and right-hand sides of the form for ease of coding. Each column of the observation form was to be used for one of the 24 10-second intervals, or four minutes of classroom interaction, for which a given page was usable. During each 10-second interval, the observer checked

Teacher ____________ Coder ____________ Date ____________ Start Time ________ Stop Time ________

STANFORD UNIVERSITY - SCHOOL OF EDUCATION
SCRDT Program on Teaching Effectiveness
RECITATION STUDY OBSERVATION SYSTEM

Class ____________ Session ____________ Page ___ of ___

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
TEACHER STRUCTURING	Reviewing																									Reviewing	TEACHER STRUCTURING
	Stating Objectives																									Stating Objectives	
	Outlining																									Outlining	
	Transitions																									Transitions	
	Important points																									Important points	
	Summarizing																									Summarizing	
	Teacher Presenting Informa.																									Teacher Presenting Infor.	
TCHR. SOLIC.	Lo questions																									Lo questions	TCHR. SOLIC.
	Hi questions																									Hi questions	
STUD. TALK	Student response																									Student response	STUD. TALK
	Student question																									Student question	
	Student comment																									Student comment	
TEACHER REACTING	Gives correct answer																									Gives correct answer	TEACHER REACTING
	Praise																									Praise	
	Neutral feedback																									Neutral Feedback	
	"No"																									"No"	
	"No" + reason																									"No" + reason	
	Redirecting																									Redirecting	
	Probing																									Probing	
	Prompting																									Prompting	
	Writing student ideas																									Writing student ideas	
	Unclassifiable																									Unclassifiable	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		

507

the one or more teaching behaviors that occurred. The form also had places for the identification of the teacher, the coder, the class, the session, the date, the starting and ending times of the session, and the page number. At the end of each session, the observer totaled the number of checks that she had made for each teaching behavior during the session.

After the training of the observers was completed, data were collected on the generalizability of the observation instrument using the procedure outlined by Cronbach, Gleser, Nanda, and Rajaratnam (1972).[1] The results of the generalizability study are described in the final report of the experiment.

Information on the reliability of the observations was also collected during the study. On various occasions, each observer was joined by a second observer who had been chosen and trained in the same way. The degree to which the two observers agreed in their observations was estimated by computing the correlation between their observations of a particular behavior for the occasions on which the two observers coded the same teaching session.

The pages that follow contain the manual that was used to train the coders in the observation system.

[1]Cronbach, L., Cleser, G., Nanda, H., & Rajaratnam, N. The dependability of behavioral measurements: Theory of generalizability for scores and profiles. New York: John Wiley and Sons, 1972.

Stanford University
School of Education
Stanford Center for Research and Development in Teaching
Program on Teaching Effectiveness

The Recitation Strategy

A teaching strategy is an overall approach that determines the way in which a teacher works with students over periods of hours, weeks, or months. One example of a strategy is the age-old lecture method. Other examples are discussion teaching, tutoring, programmed instruction, computer-assisted instruction, and simulation and gaming. The last three of these are recent, but the first-named ones have been used for many centuries.

Perhaps the most frequently used strategy at the elementary and secondary school levels is the recitation strategy. It has been studied in more research projects than any other, more is known about what goes on in classroom recitations, and it is still extremely widespread not only in the United States but throughout the world.

The classroom recitation is likely to continue to be used. Its flexibility makes it useful for a wide variety of educational objectives with students of many different kinds. Compared with programmed instruction or computer-assisted instruction, it provides you with an opportunity to do the things that only human teachers can do well--such as engage in a dialogue with students. Compared with tutoring, independent study, or self-guided study, it allows teachers to arrange for students to interact with one another in ways that help them learn the skills of working with others in democratic and productive ways. Compared with the lecture method, the classroom recitation allows teachers to find out more readily what the students are thinking and feeling, and to modify the activity accordingly.

What is the Recitation Strategy?

You have probably experienced the recitation strategy for many hours of many years of your life as a student. Why do you need to have it described? Probably, it has occurred so naturally that you never thought to notice or analyze it. But research workers have made such analyses since the early 1900's, and it is now clear that it has certain almost standard features.

The classroom recitation consists of repeated episodes of (a) structuring, (b) soliciting, (c) responding, and (d) reacting. Teachers do most, by far, of a, b, and d of these. Students do most, by far, of c. The almost essential links in this four-link chain of events are the soliciting and responding acts on the part of the teacher and a student. The structuring and reacting links do not always occur.

In a way, these are merely new words for old things. Structuring may be briefly described as telling the students what is going to happen next--what they are going to be dealing with, talking about, and handling and how you intend to deal with this material. Soliciting is about the same as question-asking, except that it need not always be a complete sentence nor stated in words. Responding refers to student answering. Reacting is what the teacher does after the student has given an answer. In the next few pages we will take a closer look at structuring, soliciting, and reacting.

Structuring

Structuring refers to the degree to which the teacher makes explicit the organization of the material to be taught, and the way in which it will be taught. Several skills can be grouped under the heading of structuring:

1. Reviewing

Reviewing can occur at two points in a lesson. At the beginning of a session, the teacher can review the main ideas and facts covered in the previous day's lesson. At the end of a teaching session, the teacher can give a brief recapitulation of the material covered that same day.

EXAMPLE: "OK class, let's review what we talked about yesterday. First, we learned that ecology is a science; second we learned that ecology deals with both living and non-living things; and third we looked at some of the kinds of relationships between living and non-living things in the environment."

2. Stating objectives

As part of the introduction to a lesson, the teacher can specify the major learning goals for the day's lesson. Objectives can include both what the students are expected to learn, how the session will be taught and what the students will be doing.

EXAMPLES: "In today's lesson I want you to learn the definition of the word ECOSYSTEM. Also, I want you to be able to give examples of how non-living things effect living things."

"After I review what you've read today, I'm going to ask you a few questions about ecosystems."

3. Outlining the lesson content

Also as part of the introduction to a lesson, the teacher can outline orally and on the chalkboard the major topics, their interrelations, and the sequence in which they will be addressed during that day's lesson.

EXAMPLE: "Here is an outline of what we'll be talking about today:"

I. Ecology

A. Science

1) Living things

2) Non-living things

relationships

4. Signaling transitions

The purpose of signaling transitions is to make it clear to the student that you have finished one part of the lesson and are moving on to the next. This can apply to both changes in the subject matter you are dealing with and changes in the way in which you are teaching.

EXAMPLES: "We've finished reviewing yesterday's lesson. Now let's begin the lesson for today."

"OK, I've given you a little lecture on how scientists show population growth by drawing a grow curve. Now I'm going to ask you some questions to see if you understood what I said."

5. Indicating important points

The teacher can help students to recognize which parts of a lesson are most important by statements like "This is a very important point," "I want you to remember this," etc. Emphasis of importance can also be conveyed by tone of voice.

6. Summarizing

Summarizing is tying together ideas or facts as the lesson proceeds.

EXAMPLES: "Let's summarize the three kinds of relationships that we've been talking about: predator-prey, benefit-no difference, and mutual benefit."

Soliciting

Soliciting refers to the kinds of questions that teachers ask students in the recitation strategy.

1. Lower order questions

Lower order questions are questions which ask the students to recall information which they have read or remember from their own general knowledge.

EXAMPLE: "What is the definition of a population?"

2. Higher order questions

Higher order questions are questions which ask the students to do more than simply recall information. Answering a higher order question usually involves reasoning. Combining facts into principles, comparing or contrasting, interpreting, evaluating, etc., are typical higher order processes.

EXAMPLE: "Why wouldn't all the birds in the foothills constitute a population?"

3. Wait time

There are two kinds of wait time. The first kind of wait time occurs at the end of a teacher solicitation. It refers to the length of time in seconds that the teacher will wait in silence before a student is called upon to respond. The second kind of wait time occurs immediately after a student has responded. This kind of wait time refers to the amount of time in seconds that the teacher waits in silence before reacting to the student's response.

Reacting

Reacting refers to what a teacher says immediately after a student comment. What a teacher says when reacting can take several forms:

1. Praise

Praise is a positive way of reacting to a student comment. This kind of reacting is appropriate when a student gives correct or partially correct information.

EXAMPLES: "Very good!"; "Right!"; "Good answer!"; "Excellent!"

2. Neutral feedback

Neutral feedback is a simple acknowledgement by the teacher of a student comment. Neutral feedback involves neither positive nor negative evaluation of the student comment.

EXAMPLE: "OK"; "Uh huh."

3. Corrective feedback

There are two kinds of corrective feedback. One kind involves telling a student that his comment was incorrect by simply saying the word "No." The other kind of corrective feedback involves telling a student that the comment was incorrect by saying "No" and then providing a reason why the comment was incorrect.

4. Probing

Probing is asking a student to continue or elaborate a response to a question.

EXAMPLE: "Anything else?"

"Can you tell me more?"

5. Prompting

Prompting involves asking a student to continue or elaborate a response (probing) plus providing a clue or hint about what that response should be.

EXAMPLES: "The first part of what you said was right--all the birds in the foothills are members of the same community--but how is a community different from a population?"

6. Using student ideas

Using student ideas refers to writing all or part of a correct student comment on the chalkboard.

7. Redirecting

Redirecting refers to asking a second student to answer a question after a first student has failed to answer correctly.

EXAMPLE: "No, that's not what I had in mind. Penny, do you know?"

Three major clusters of teacher skills are listed and described above. These clusters make up the major ways in which your teaching will be varied during this study.

It is important that all of us--the study's staff and its teachers--recognize that none of these kinds of action can at this point be considered as necessarily or probably more desirable than their opposites. So-called "high structuring" is not, so far as we now know, more desirable or effective in any way than so-called "low structuring." The same is true of "high soliciting" vs. "low soliciting." It is also true of "high reacting" vs. "low reacting." Finally, it is also true of the eight different combinations of high and low structuring, soliciting, and reacting.

Indeed, the purpose of the study is exactly that of obtaining knowledge that will provide a better basis for judging these different kinds of teacher behavior. But the study should be carried out without any expectation or hypothesis on anyone's part that one kind of action is better in any sense than another kind. To have or hold such an expectation might bias the execution and interpretation of the study in ways that might invalidate the whole enterprise.

In short, let us attempt throughout this study, insofar as is humanly possible, to avoid any presupposition or prejudice concerning the desirability of these kinds of teaching. So far as we now know, all are equally desirable and that should be our assumption until all the data have been collected and analyzed.

Recognition Exercise

Fill in each blank with the name of the teaching skill that the teacher is using.

Teacher: Alright, let's spend a few minutes talking about the alligator and its place in the balance of nature. 1.______________. You've all read a little bit about where alligators live, what they eat and how humans have affected the size of their population. 2.______________. I'm going to ask a few questions about what you read to be sure that everyone understands and remembers the main ideas covered in your reading. 3.______________. After we're done with the questions and answers I'll briefly summarize the lesson for you. 4.______________.

Penny, in what part of the country are most alligators found? 5.______________.

Penny: The south.

Teacher: OK, the south. 6.______________. [Teacher writes answer on chalkboard.] 7.______________.

Teacher: Ron, the alligator is a natural enemy of what fish? 8.______________.

Ron: Bass.

Teacher: No, alligators protect bass. 9.______________. Phil, do you know? 10.______________.

Phil: The garfish.

Teacher: That's right Phil, good! 11.______________. The alligator is a natural enemy of the garfish. [Teacher writes "garfish" on the chalkboard.] 12.______________. OK, let's summarize what we've said so far. Garfish like to eat bass and other small fish. By feeding on garfish, the alligator protects the bass and other game fish. 13.______________.

Teacher: How does the alligator help maintain the balance of nature? 14.______________.

Mortimer: The alligator helps maintain the balance of nature by protecting other fish like bass from the garfish. Also, the gator hole helps many animals survive during the dry period.

Teacher: Terrific! 15.______________. That's a very important thing to remember. 16______________. You really got the picture on how alligators and the things they do affect many of the other creatures that share the same environment. 17.______________. [Teacher writes key parts of answer on chalkboard.] 18.______________.

Teacher: OK, who can name some things that alligator skins are used for? Ron? 19.______________.

Ron: Boots.

Teacher: Anything else, Ron? 20.___________________.

Ron: Belts and handbags.

Teacher: Good! 21.______________.

Teacher: This next question really requires you to pull a lot of important things together. 22.______________. What influence have people had on the balance of nature in the Everglades? 23.______________. Penny?

Penny: I, uh, uh, I don't know.

Teacher: Think about the rangers and what they do. 24.______________.

Penny: Oh, yeah, the rangers. The rangers had to capture garfish when there were not enough alligators to eat them up.

Teacher: OK. 25.______________.

Answers to Recognition Exercise

1. Signaling transition
2. Reviewing
3. Stating objectives
4. Stating objectives
5. Lower order question
6. Neutral feedback
7. Using student ideas
8. Lower order question
9. Corrective feedback
10. Redirecting
11. Praising
12. Using student ideas
13. Summarizing
14. Higher order question
15. Praising
16. Indicating important point
17. Praising
18. Using student ideas
19. Lower order question
20. Probing
21. Praising
22. Indicating important point
23. Higher order question
24. Prompting
25. Neutral feedback

APPENDIX E

OF

A FACTORIALLY DESIGNED EXPERIMENT ON

TEACHER STRUCTURING, SOLICITING, AND REACTING

November 1976

ADDITIONAL TABLES AND FIGURES

Program on Teaching Effectiveness

Stanford Center for Research and Development in Teaching

TABLE 1

Equations for the expected mean squares with Structuring (STR), Soliciting (SOL), and Reacting (REA) considered fixed effects, and Teacher (TCHR) considered a random effect*

Source	Equation for the Expected Mean Squares	df	Error Term
A (STR)	$\sigma_e^2 + qrt\sigma_{AD}^2 + qrst\sigma_A^2$	1	AD
B (SOL)	$\sigma_e^2 + prt\sigma_{BD}^2 + prst\sigma_B^2$	1	BD
C (REA)	$\sigma_e^2 + pqt\sigma_{CD}^2 + pqst\sigma_C^2$	1	CD
D (TCHR)	$\sigma_e^2 + pqrt\sigma_D^2$	3	S(ABCD)
AB	$\sigma_e^2 + rt\sigma_{ABD}^2 + rst\sigma_{AB}^2$	1	ABD
AC	$\sigma_e^2 + qt\sigma_{ACD}^2 + qst\sigma_{AC}^2$	1	ACD
AD	$\sigma_e^2 + qrt\sigma_{AD}^2$	3	S(ABCD)
BC	$\sigma_e^2 + pt\sigma_{BCD}^2 + pst\sigma_{BC}^2$	1	BCD
BD	$\sigma_e^2 + prt\sigma_{BD}^2$	3	S(ABCD)
CD	$\sigma_e^2 + pqt\sigma_{CD}^2$	3	S(ABCD)
ABC	$\sigma_e^2 + t\sigma_{ABCD}^2 + st\sigma_{ABC}^2$	1	ABCD
ABD	$\sigma_e^2 + rt\sigma_{ABD}^2$	3	S(ABCD)
ACD	$\sigma_e^2 + qt\sigma_{ACD}^2$	3	S(ABCD)
BCD	$\sigma_e^2 + pt\sigma_{BCD}^2$	3	S(ABCD)
ABCD	$\sigma_e^2 + t\sigma_{ABCD}^2$	3	S(ABCD)
S(ABCD)	σ_e^2	354	--

*Where A (STR) has p levels
B (SOL) has q levels
C (REA) has r levels
D (TCHR) has s levels
S (Students) has t levels

TABLE 2

Means and Standard Deviations of Adjusted Total Scores on the Multiple-Choice Achievement Posttest by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 19.77 SD = .96 N = 4	HH*: $\bar{X}$ = 19.92 SD = .80 N = 8	H*H: $\bar{X}$ = 20.61 SD = 1.84 N = 8	*HH: $\bar{X}$ = 19.97 SD = 1.45 N = 8	H**: $\bar{X}$ = 20.66 SD = 1.47 N = 16	*H*: $\bar{X}$ = 19.77 SD = 1.18 N = 16	**H: $\bar{X}$ = 2[illegible] SD = [illegible] N = 1[illegible]
HHL: $\bar{X}$ = 20.06 SD = .73 N = 4						
HLH: $\bar{X}$ = 21.44 SD = 2.27 N = 4	HL*: $\bar{X}$ = 21.41 SD = 1.64 N = 8	H*L: $\bar{X}$ = 20.72 SD = 1.10 N = 8	*HL: $\bar{X}$ = 19.57 SD = .89 N = 8			
HLL: $\bar{X}$ = 21.38 SD = 1.07 N = 4						
LHH: $\bar{X}$ = 20.16 SD = 1.96 N = 4	LH*: $\bar{X}$ = 19.62 SD = 1.51 N = 8	L*H: $\bar{X}$ = 20.88 SD = 1.93 N = 8	*LH: $\bar{X}$ = 21.51 SD = 1.92 N = 8	L**: $\bar{X}$ = 20.24 SD = 1.58 N = 16	*L*: $\bar{X}$ = 21.13 SD = 1.54 N = 16	**L: $\bar{X}$ = 20[illegible] SD = 1[illegible] N = 16
LHL: $\bar{X}$ = 19.07 SD = .80 N = 4						
LLH: $\bar{X}$ = 21.59 SD = 1.87 N = 4	LL*: $\bar{X}$ = 20.86 SD = 1.48 N = 8	L*L: $\bar{X}$ = 19.60 SD = .84 N = 8	*LL: $\bar{X}$ = 20.75 SD = 1.02 N = 8			
LLL: $\bar{X}$ = 20.13 SD = .48 N = 4						

TABLE 3

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Posttest, Lower-Order, Text-and-Teacher-as-Source Items, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 5.04, SD = .62, N = 4	HH*: $\bar{X}$ = 5.17, SD = .52, N = 8	H*H: $\bar{X}$ = 5.26, SD = .57, N = 8	*HH: $\bar{X}$ = 5.67, SD = .45, N = 8			
HHL: $\bar{X}$ = 5.30, SD = .45, N = 4				H**: $\bar{X}$ = 5.41, SD = .55, N = 16	*H*: $\bar{X}$ = 5.11, SD = .42, N = 16	**H: $\bar{X}$ = 5.41, SD = .57, N = 16
HLH: $\bar{X}$ = 5.47, SD = .49, N = 4	HL*: $\bar{X}$ = 5.64, SD = .50, N = 8	H*L: $\bar{X}$ = 5.55, SD = .52, N = 8	*HL: $\bar{X}$ = 5.16, SD = .40, N = 8			
HLL: $\bar{X}$ = 5.80, SD = .52, N = 4						
LHH: $\bar{X}$ = 5.09, SD = .30, N = 4	LH*: $\bar{X}$ = 5.05, SD = .31, N = 8	L*H: $\bar{X}$ = 5.56, SD = .57, N = 8	*LH: $\bar{X}$ = 5.74, SD = .47, N = 8			
LHL: $\bar{X}$ = 5.01, SD = .35, N = 4				L**: $\bar{X}$ = 5.34, SD = .53, N = 16	*L*: $\bar{X}$ = 5.63, SD = .52, N = 16	**L: $\bar{X}$ = 5.34, SD = .51, N = 16
LLH: $\bar{X}$ = 6.02, SD = .30, N = 4	LL*: $\bar{X}$ = 5.63, SD = .57, N = 8	L*L: $\bar{X}$ = 5.12, SD = .42, N = 8	*LL: $\bar{X}$ = 5.52, SD = .56, N = 8			
LLL: $\bar{X}$ = 5.24, SD = .51, N = 4						

TABLE 4

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Posttest, Higher-Order, Text-and-Teacher-as-Source Items, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 5.34, SD = .59, N = 4	HH*: $\bar{X}$ = 5.33, SD = .42, N = 8	H*H: $\bar{X}$ = 5.46, SD = .60, N = 8	*HH: $\bar{X}$ = 5.48, SD = .76, N = 8			
HHL: $\bar{X}$ = 5.32, SD = .24, N = 4				H**: $\bar{X}$ = 5.43, SD = .44, N = 16	*H*: $\bar{X}$ = 5.37, SD = .55, N = 16	**H: $\bar{X}$ = 5.47, SD = .71, N = 16
HLH: $\bar{X}$ = 5.58, SD = .67, N = 4	HL*: $\bar{X}$ = 5.52, SD = .46, N = 8	H*L: $\bar{X}$ = 5.39, SD = .22, N = 8	*HL: $\bar{X}$ = 5.26, SD = .22, N = 8			
HLL: $\bar{X}$ = 5.46, SD = .20, N = 4						
LHH: $\bar{X}$ = 5.62, SD = .97, N = 4	LH*: $\bar{X}$ = 5.41, SD = .69, N = 8	L*H: $\bar{X}$ = 5.49, SD = .85, N = 8	*LH: $\bar{X}$ = 5.47, SD = .71, N = 8			
LHL: $\bar{X}$ = 5.19, SD = .21, N = 4				L**: $\bar{X}$ = 5.39, SD = .62, N = 16	*L*: $\bar{X}$ = 5.44, SD = .32, N = 16	**L: $\bar{X}$ = 5.34, SD = .26, N = 16
LLH: $\bar{X}$ = 5.35, SD = .83, N = 4	LL*: $\bar{X}$ = 5.37, SD = .60, N = 8	L*L: $\bar{X}$ = 5.29, SD = .30, N = 8	*LL: $\bar{X}$ = 5.42, SD = .28, N = 8			
LLL: $\bar{X}$ = 5.38, SD = .37, N = 4						

TABLE 5

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Posttest, Lower-Order, Teacher-Only-as-Source Items, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 4.71 SD = .71 N = 4	HH*: $\bar{X}$ = 4.68 SD = .58 N = 8	H*H: $\bar{X}$ = 4.93 SD = .73 N = 8	*HH: $\bar{X}$ = 4.54 SD = .60 N = 8	H**: $\bar{X}$ = 4.83 SD = .60 N = 16	*H*: $\bar{X}$ = 4.51 SD = .51 N = 16	**H: $\bar{X}$ = 4.77 SD = .62 N = 16
HHL: $\bar{X}$ = 4.65 SD = .53 N = 4						
HLH: $\bar{X}$ = 5.16 SD = .76 N = 4	HL*: $\bar{X}$ = 4.99 SD = .62 N = 8	H*L: $\bar{X}$ = 4.73 SD = .48 N = 8	*HL: $\bar{X}$ = 4.47 SD = .44 N = 8			
HLL: $\bar{X}$ = 4.82 SD = .47 N = 4						
LHH: $\bar{X}$ = 4.37 SD = .52 N = 4	LH*: $\bar{X}$ = 4.33 SD = .38 N = 8	L*H: $\bar{X}$ = 4.60 SD = .47 N = 8	*LH: $\bar{X}$ = 5.00 SD = .57 N = 8	L**: $\bar{X}$ = 4.55 SD = .40 N = 16	*L*: $\bar{X}$ = 4.88 SD = .48 N = 16	**L: $\bar{X}$ = 4.61 SD = .41 N = 16
LHL: $\bar{X}$ = 4.29 SD = .27 N = 4						
LLH: $\bar{X}$ = 4.83 SD = .34 N = 4	LL*: $\bar{X}$ = 4.77 SD = .29 N = 8	L*L: $\bar{X}$ = 4.49 SD = .32 N = 8	*LL: $\bar{X}$ = 4.76 SD = .36 N = 8			
LLL: $\bar{X}$ = 4.70 SD = .25 N = 4						

TABLE 6

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Posttest, Higher-Order, Teacher-Only-as-Source Items, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 4.68 SD = .24 N = 4	HH*: $\bar{X}$ = 4.76 SD = .33 N = 8	H*H: $\bar{X}$ = 4.95 SD = .53 N = 8	*HH: $\bar{X}$ = 4.88 SD = .34 N = 8			
HHL: $\bar{X}$ = 4.84 SD = .43 N = 4				H**: $\bar{X}$ = 5.00 SD = .45 N = 16	*H*: $\bar{X}$ = 4.78 SD = .47 N = 16	**H: $\bar{X}$ = 5.09 SD = .61 N = 16
HLH: $\bar{X}$ = 5.22 SD = .64 N = 4	HL*: $\bar{X}$ = 5.25 SD = .44 N = 8	H*L: $\bar{X}$ = 5.06 SD = .39 N = 8	*HL: $\bar{X}$ = 4.68 SD = .59 N = 8			
HLL: $\bar{X}$ = 5.28 SD = .20 N = 4						
LHH: $\bar{X}$ = 5.08 SD = .33 N = 4	LH*: $\bar{X}$ = 4.80 SD = .61 N = 8	L*H: $\bar{X}$ = 5.24 SD = .69 N = 8	*LH: $\bar{X}$ = 5.31 SD = .77 N = 8			
LHL: $\bar{X}$ = 4.52 SD = .74 N = 4				L**: $\bar{X}$ = 4.97 SD = .70 N = 16	*L*: $\bar{X}$ = 5.19 SD = .62 N = 16	**L: $\bar{X}$ = 4.88 SD = .54 N = 16
LLH: $\bar{X}$ = 5.39 SD = .97 N = 4	LL*: $\bar{X}$ = 5.13 SD = .78 N = 8	L*L: $\bar{X}$ = 4.69 SD = .64 N = 8	*LL: $\bar{X}$ = 5.07 SD = .45 N = 8			
LLL: $\bar{X}$ = 4.87 SD = .56 N = 4						

TABLE 7

Means and Standard Deviations of Adjusted Essay Posttest Scores, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 1.68 SD = .78 N = 4	HH*: $\bar{X}$ = 1.64 SD = .62 N = 8	H*H: $\bar{X}$ = 1.63 SD = 1.10 N = 8	*HH: $\bar{X}$ = 1.81 SD = .53 N = 8	H**: $\bar{X}$ = 1.65 SD = .83 N = 16	*H*: $\bar{X}$ = 1.73 SD = .58 N = 16	**H: $\bar{X}$ = 1.86 SD = .82 N = 16
HHL: $\bar{X}$ = 1.60 SD = .54 N = 4						
HLH: $\bar{X}$ = 1.57 SD = 1.50 N = 4	HL*: $\bar{X}$ = 1.66 SD = 1.05 N = 8	H*L: $\bar{X}$ = 1.67 SD = .52 N = 8	*HL: $\bar{X}$ = 1.65 SD = .67 N = 8			
HLL: $\bar{X}$ = 1.75 SD = .56 N = 4						
LHH: $\bar{X}$ = 1.93 SD = .04 N = 4	LH*: $\bar{X}$ = 1.82 SD = .57 N = 8	L*H: $\bar{X}$ = 2.10 SD = .32 N = 8	*LH: $\bar{X}$ = 1.92 SD = 1.08 N = 8	L**: $\bar{X}$ = 1.86 SD = .54 N = 16	*L*: $\bar{X}$ = 1.78 SD = .82 N = 16	**L: $\bar{X}$ = 1.64 SD = .56 N = 16
LHL: $\bar{X}$ = 1.71 SD = .85 N = 4						
LLH: $\bar{X}$ = 2.27 SD = .40 N = 4	LL*: $\bar{X}$ = 1.89 SD = .55 N = 8	L*L: $\bar{X}$ = 1.62 SD = .63 N = 8	*LL: $\bar{X}$ = 1.63 SD = .47 N = 8			
LLL: $\bar{X}$ = 1.52 SD = .42 N = 4						

TABLE 8

Means and Standard Deviations of Adjusted Attitude-toward-Ecology Posttest Scores, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 43.26 SD = .79 N = 4	HH*: $\bar{X}$ = 43.06 SD = 1.07 N = 8	H*H: $\bar{X}$ = 42.38 SD = 1.89 N = 8	*HH: $\bar{X}$ = 43.28 SD = 1.22 N = 8	H**: $\bar{X}$ = 42.57 SD = 1.73 N = 16	*H*: $\bar{X}$ = 42.77 SD = 1.47 N = 16	**H: $\bar{X}$ = 43.11 SD = 2.75 N = 16
HHL: $\bar{X}$ = 42.86 SD = 1.39 N = 4						
HLH: $\bar{X}$ = 41.50 SD = 2.36 N = 4	HL*: $\bar{X}$ = 42.07 SD = 2.17 N = 8	H*L: $\bar{X}$ = 42.75 SD = 1.67 N = 8	*HL: $\bar{X}$ = 42.27 SD = 1.61 N = 8			
HLL: $\bar{X}$ = 42.65 SD = 2.13 N = 4						
LHH: $\bar{X}$ = 43.30 SD = 1.68 N = 4	LH*: $\bar{X}$ = 42.49 SD = 1.82 N = 8	L*H: $\bar{X}$ = 43.83 SD = 3.38 N = 8	*LH: $\bar{X}$ = 42.94 SD = 3.82 N = 8	L**: $\bar{X}$ = 43.15 SD = 2.71 N = 16	*L*: $\bar{X}$ = 42.94 SD = 2.89 N = 16	**L: $\bar{X}$ = 42.61 SD = 1.69 N = 16
LHL: $\bar{X}$ = 41.68 SD = 1.78 N = 4						
LLH: $\bar{X}$ = 44.37 SD = 4.80 N = 4	LL*: $\bar{X}$ = 43.82 SD = 3.38 N = 8	L*L: $\bar{X}$ = 42.47 SD = 1.80 N = 8	*LL: $\bar{X}$ = 42.95 SD = 1.80 N = 8			
LLL: $\bar{X}$ = 43.26 SD = 1.66 N = 4						

TABLE 9

Means and Standard Deviations of Adjusted Total Scores on the Multiple-Choice Achievement Retention Test, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL
HHH: $\bar{X}$ = 18.16 SD = 1.35 N = 4	HH*: $\bar{X}$ = 18.85 SD = 1.83 N = 8	H*H: $\bar{X}$ = 19.17 SD = 1.81 N = 8	*HH: $\bar{X}$ = 18.72 SD = 1.89 N = 8		
HHL: $\bar{X}$ = 19.54 SD = 2.18 N = 4				H**: $\bar{X}$ = 19.34 SD = 1.78 N = 16	*H*: $\bar{X}$ = 18.45 SD = 2.00 N = 16
HLH: $\bar{X}$ = 20.19 SD = 1.75 N = 4	HL*: $\bar{X}$ = 19.83 SD = 1.69 N = 8	H*L: $\bar{X}$ = 19.50 SD = 1.85 N = 8	*HL: $\bar{X}$ = 18.18 SD = 2.21 N = 8		
HLL: $\bar{X}$ = 19.46 SD = 1.80 N = 4					
LHH: $\bar{X}$ = 19.28 SD = 2.38 N = 4	LH*: $\bar{X}$ = 18.05 SD = 2.21 N = 8	L*H: $\bar{X}$ = 19.76 SD = 2.06 N = 8	*LH: $\bar{X}$ = 20.22 SD = 1.70 N = 8		
LHL: $\bar{X}$ = 16.82 SD = 1.30 N = 4				L**: $\bar{X}$ = 18.55 SD = 2.07 N = 16	*L*: $\bar{X}$ = 19.43 SD = 1.81 N = 16
LLH: $\bar{X}$ = 20.24 SD = 1.91 N = 4	LL*: $\bar{X}$ = 19.04 SD = 1.94 N = 8	L*L: $\bar{X}$ = 17.33 SD = 1.25 N = 8	*LL: $\bar{X}$ = 18.65 SD = 1.64 N = 8		
LLL: $\bar{X}$ = 17.84 SD = 1.14 N = 4					

TABLE 10

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Retention Test, Lower-Order, Text-and-Teacher-as-Source Items, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 4.29 SD = .35 N = 4	HH*: $\bar{X}$ = 4.58 SD = .52 N = 8	H*H: $\bar{X}$ = 4.71 SD = .70 N = 8	*HH: $\bar{X}$ = 4.67 SD = .53 N = 8			
HHL: $\bar{X}$ = 4.87 SD = .53 N = 4				H**: $\bar{X}$ = 4.82 SD = .62 N =16	*H*: $\bar{X}$ = 4.68 SD = .54 N =16	**H: $\bar{X}$ = 4.90 SD = .60 N =16
HLH: $\bar{X}$ = 5.12 SD = .76 N = 4	HL*: $\bar{X}$ = 4.06 SD = .65 N = 8	H*L: $\bar{X}$ = 4.93 SD = .54 N = 8	*HL: $\bar{X}$ = 4.68 SD = .58 N = 8			
HLL: $\bar{X}$ = 4.99 SD = .62 N = 4						
LHH: $\bar{X}$ = 5.06 SD = .38 N = 4	LH*: $\bar{X}$ = 4.77 SD = .58 N = 8	L*H: $\bar{X}$ = 5.09 SD = .44 N = 8	*LH: $\bar{X}$ = 5.13 SD = .62 N = 8			
LHL: $\bar{X}$ = 4.49 SD = .65 N = 4				L**: $\bar{X}$ = 4.80 SD = .56 N = 16	*L*: $\bar{X}$ = 4.94 SD = .60 N = 16	**L: $\bar{X}$ = 4.72 SD = .56 N = 16
LLH: $\bar{X}$ = 5.13 SD = .56 N = 4	LL*: $\bar{X}$ = 4.83 SD = .57 N = 8	L*L: $\bar{X}$ = 4.51 SD = .52 N = 8	*LL: $\bar{X}$ = 4.76 SD = .56 N = 8			
LLL: $\bar{X}$ = 4.53 SD = .46 N = 4						

TABLE 11

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Retention Test, Higher-Order, Text-and-Teacher-as-Source Items, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 5.05 SD = .72 N = 4	HH*: $\bar{X}$ = 5.17 SD = .74 N = 8	H*H: $\bar{X}$ = 5.26 SD = .58 N = 8	*HH: $\bar{X}$ = 5.22 SD = .81 N = 8			
HHL: $\bar{X}$ = 5.29 SD = .85 N = 4				H**: $\bar{X}$ = 5.27 SD = .57 N = 16	*H*: $\bar{X}$ = 5.10 SD = .76 N = 16	**H: $\bar{X}$ = 5.29 SD = .68 N = 16
HLH: $\bar{X}$ = 5.46 SD = .38 N = 4	HL*: $\bar{X}$ = 5.37 SD = .36 N = 8	H*L: $\bar{X}$ = 5.28 SD = .60 N = 8	*HL: $\bar{X}$ = 4.97 SD = .72 N = 8			
HLL: $\bar{X}$ = 5.27 SD = .37 N = 4						
LHH: $\bar{X}$ = 5.40 SD = .97 N = 4	LH*: $\bar{X}$ = 5.02 SD = .81 N = 8	L*H: $\bar{X}$ = 5.32 SD = .80 N = 8	*LH: $\bar{X}$ = 5.35 SD = .55 N = 8			
LHL: $\bar{X}$ = 4.65 SD = .48 N = 4				L**: $\bar{X}$ = 5.07 SD = .65 N = 16	*L*: $\bar{X}$ = 5.24 SD = .44 N = 16	**L: $\bar{X}$ = 5.05 SD = .54 N = 16
LLH: $\bar{X}$ = 5.24 SD = .72 N = 4	LL*: $\bar{X}$ = 5.11 SD = .50 N = 8	L*L: $\bar{X}$ = 4.82 SD = .37 N = 8	*LL: $\bar{X}$ = 5.13 SD = .30 N = 8			
LLL: $\bar{X}$ = 4.50 SD = .14 N = 4						

TABLE 12

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Retention Test, Lower-Order, Teacher-Only-as-Source Items, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 4.29 SD = .49 N = 4	HH*: $\bar{X}$ = 4.43 SD = .45 N = 8	H*H: $\bar{X}$ = 4.39 SD = .38 N = 8	*HH: $\bar{X}$ = 4.07 SD = .47 N = 8			
HHL: $\bar{X}$ = 4.38 SD = .47 N = 4				H**: $\bar{X}$ = 4.37 SD = .43 N = 16	*H*: $\bar{X}$ = 3.98 SD = .58 N = 16	**H: $\bar{X}$ = 4.29 SD = .44 N = 16
HLH: $\bar{X}$ = 4.49 SD = .26 N = 4	HL*: $\bar{X}$ = 4.41 SD = .44 N = 8	H*L: $\bar{X}$ = 4.36 SD = .50 N = 8	*HL: $\bar{X}$ = 3.89 SD = .70 N = 8			
HLL: $\bar{X}$ = 4.33 SD = .60 N = 4						
LHH: $\bar{X}$ = 3.85 SD = .39 N = 4	LH*: $\bar{X}$ = 3.63 SD = .50 N = 8	L*H: $\bar{X}$ = 4.19 SD = .50 N = 8	*LH: $\bar{X}$ = 4.50 SD = .30 N = 8			
LHL: $\bar{X}$ = 3.41 SD = .54 N = 4				L**: $\bar{X}$ = 3.91 SD = .60 N = 16	*L*: $\bar{X}$ = 4.30 SD = .51 N = 16	**L: $\bar{X}$ = 3.99 SD = .64 N = 16
LLH: $\bar{X}$ = 4.52 SD = .37 N = 4	LL*: $\bar{X}$ = 4.19 SD = .59 N = 8	L*L: $\bar{X}$ = 3.63 SD = .59 N = 8	*LL: $\bar{X}$ = 4.10 SD = .61 N = 8			
LLL: $\bar{X}$ = 3.86 SD = .61 N = 4						

TABLE 13

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Retention Test, Higher-Order, Teacher-Only-as-Source Items, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 4.49 SD = .65 N = 4	HH*: $\bar{X}$ = 4.73 SD = .63 N = 8	H*H: $\bar{X}$ = 4.82 SD = .69 N = 8	*HH: $\bar{X}$ = 4.73 SD = .76 N = 8	H**: $\bar{X}$ = 4.87 SD = .60 N = 16	*H*: $\bar{X}$ = 4.68 SD = .67 N = 16	**H: $\bar{X}$ = 4.99 SD = .72 N = 16
HHL: $\bar{X}$ = 4.97 SD = .58 N = 4						
HLH: $\bar{X}$ = 5.14 SD = .65 N = 4	HL*: $\bar{X}$ = 5.00 SD = .58 N = 8	H*L: $\bar{X}$ = 4.91 SD = .53 N = 8	*HL: $\bar{X}$ = 4.62 SD = .62 N = 8			
HLL: $\bar{X}$ = 4.86 SD = .56 N = 4						
LHH: $\bar{X}$ = 4.97 SD = .87 N = 4	LH*: $\bar{X}$ = 4.62 SD = .76 N = 8	L*H: $\bar{X}$ = 5.16 SD = .76 N = 8	*LH: $\bar{X}$ = 5.24 SD = .63 N = 8	L**: $\bar{X}$ = 4.77 SD = .73 N = 16	*L*: $\bar{X}$ = 4.96 SD = .63 N = 16	**L: $\bar{X}$ = 4.65 SD = .56 N = 16
LHL: $\bar{X}$ = 4.27 SD = .49 N = 4						
LLH: $\bar{X}$ = 5.35 SD = .69 N = 4	LL*: $\bar{X}$ = 4.93 SD = .71 N = 8	L*L: $\bar{X}$ = 4.39 SD = .47 N = 8	*LL: $\bar{X}$ = 4.68 SD = .52 N = 8			
LLL: $\bar{X}$ = 4.51 SD = .49 N = 4						

TABLE 14

Means and Standard Deviations of Adjusted Essay Retention Test Scores, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 1.12 SD = .51 N = 4	HH*: $\bar{X}$ = .84 SD = .48 N = 8	H*H: $\bar{X}$ = 1.29 SD = .83 N = 8	*HH: $\bar{X}$ = 1.19 SD = .51 N = 8			
HHL: $\bar{X}$ = .56 SD = .25 N = 4				H**: $\bar{X}$ = 1.06 SD = .77 N = 16	*H*: $\bar{X}$ = .89 SD = .50 N = 16	**H: $\bar{X}$ = 1.34 SD = .71 N = 16
HLH: $\bar{X}$ = 1.45 SD = 1.14 N = 4	HL*: $\bar{X}$ = 1.27 SD = .96 N = 8	H*L: $\bar{X}$ = .83 SD = .67 N = 8	*HL: $\bar{X}$ = .59 SD = .25 N = 8			
HLL: $\bar{X}$ = 1.10 SD = .89 N = 4						
LHH: $\bar{X}$ = 1.26 SD = .57 N = 4	LH*: $\bar{X}$ = .94 SD = .54 N = 8	L*H: $\bar{X}$ = 1.39 SD = .62 N = 8	*LH: $\bar{X}$ = 1.48 SD = .88 N = 8			
LHL: $\bar{X}$ = .63 SD = .29 N = 4				L**: $\bar{X}$ = 1.00 SD = .67 N = 16	*L*: $\bar{X}$ = 1.17 SD = .86 N = 16	**L: $\bar{X}$ = .72 SD = .57 N = 16
LLH: $\bar{X}$ = 1.51 SD = .73 N = 4	LL*: $\bar{X}$ = 1.06 SD = .81 N = 8	L*L: $\bar{X}$ = .61 SD = .47 N = 8	*LL: $\bar{X}$ = .85 SD = .77 N = 8			
LLL: $\bar{X}$ = .60 SD = .65 N = 4						

TABLE 15

Means and Standard Deviations of Adjusted Attitude-toward-Ecology Retention Test Scores, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 40.26 SD = 1.32 N = 4	HH*: $\bar{X}$ = 40.61 SD = 1.55 N = 8	H*H: $\bar{X}$ = 40.08 SD = 1.42 N = 8	*HH: $\bar{X}$ = 40.78 SD = 1.84 N = 8			
HHL: $\bar{X}$ = 40.96 SD = 1.89 N = 4				H**: $\bar{X}$ = 40.32 SD = 1.50 N = 16	*H*: $\bar{X}$ = 40.65 SD = 1.65 N = 16	**H: $\bar{X}$ = 40.58 SD = 2.08 N = 16
HLH: $\bar{X}$ = 39.90 SD = 1.70 N = 4	HL*: $\bar{X}$ = 40.03 SD = 1.49 N = 8	H*L: $\bar{X}$ = 40.56 SD = 1.63 N = 8	*HL: $\bar{X}$ = 40.51 SD = 1.56 N = 8			
HLL: $\bar{X}$ = 40.16 SD = 1.50 N = 4						
LHH: $\bar{X}$ = 41.31 SD = 2.33 N = 4	LH*: $\bar{X}$ = 40.69 SD = 1.86 N = 8	L*H: $\bar{X}$ = 41.08 SD = 2.58 N = 8	*LH: $\bar{X}$ = 40.37 SD = 2.40 N = 8			
LHL: $\bar{X}$ = 40.07 SD = 1.26 N = 4				L**: $\bar{X}$ = 40.86 SD = 2.26 N = 16	*L*: $\bar{X}$ = 40.53 SD = 2.18 N = 16	**L: $\bar{X}$ = 40.60 SD = 1.78 N = 16
LLH: $\bar{X}$ = 40.85 SD = 3.16 N = 4	LL*: $\bar{X}$ = 41.03 SD = 2.72 N = 8	L*L: $\bar{X}$ = 40.64 SD = 2.03 N = 8	*LL: $\bar{X}$ = 40.68 SD = 2.09 N = 8			
LLL: $\bar{X}$ = 41.21 SD = 2.68 N = 4						

TABLE 16

Means and Standard Deviations of Adjusted Scores on the True-False-? Retention Test, by Treatment (N=32 Half-Classes)

STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH: $\bar{X}$ = 11.22 SD = 1.47 N = 4 HHL: $\bar{X}$ = 11.77 SD = 1.61 N = 4	HH*: $\bar{X}$ = 11.50 SD = 1.46 N = 8	H*H: $\bar{X}$ = 11.66 SD = 1.15 N = 8	*HH: $\bar{X}$ = 11.32 SD = 1.05 N = 8	H**: $\bar{X}$ = 11.58 SD = 1.12 N = 16	*H*: $\bar{X}$ = 11.51 SD = 1.24 N = 16	**H: $\bar{X}$ = 11.46 SD = .96 N = 16
HLH: $\bar{X}$ = 12.10 SD = .67 N = 4 HLL: $\bar{X}$ = 11.25 SD = .56 N = 4	HL*: $\bar{X}$ = 11.67 SD = .73 N = 8	H*L: $\bar{X}$ = 11.51 SD = 1.15 N = 8	*HL: $\bar{X}$ = 11.70 SD = 1.45 N = 8			
LHH: $\bar{X}$ = 11.42 SD = .62 N = 4 LHL: $\bar{X}$ = 11.63 SD = 1.51 N = 4	LH*: $\bar{X}$ = 11.53 SD = 1.07 N = 8	L*H: $\bar{X}$ = 11.26 SD = .73 N = 8	*LH: $\bar{X}$ = 11.60 SD = .91 N = 8	L**: $\bar{X}$ = 11.19 SD = 1.05 N = 16	*L*: $\bar{X}$ = 11.26 SD = .93 N = 16	**; $\bar{X}$ = 11.31 SD = 1.22 N = 16
LLH: $\bar{X}$ = 11.10 SD = .90 N = 4 LLL: $\bar{X}$ = 10.58 SD = 1.09 N = 4	LL*: $\bar{X}$ = 10.84 SD = .96 N = 8	L*L: $\bar{X}$ = 11.11 SD = 1.34 N = 8	*LL: $\bar{X}$ = 10.92 SD = .87 N = 8			

TABLE 17

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Posttest, by Treatment (N=386 Pupils)

STR X SOL X REA X TCHR: TRMT	TCHR	$\bar{X}$	SD	N	STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH	1	20.998	3.770	13	HHH:						
	2	19.552	4.762	15	$\bar{X}$ = 19.788	HH*:	H*H:	*HH:			
	3	18.576	4.258	12	SD = 4.445						
	4	19.971	5.015	13	N = 53	$\bar{X}$ = 19.920	$\bar{X}$ = 20.682	$\bar{X}$ = 19.950			
						SD = 4.364	SD = 4.314	SD = 4.518			
HHL	1	20.927	4.902	14	HHL:	N = 107	N = 99	N = 99			
	2	20.486	3.332	12	$\bar{X}$ = 20.049				H**:	*H*:	**H:
	3	19.375	4.703	15	SD = 4.322				$\bar{X}$ = 20.658	$\bar{X}$ = 19.764	$\bar{X}$ = 20.749
	4	19.477	4.297	13	N = 54				SD = 4.515	SD = 4.568	SD = 4.435
HLH	1	24.514	3.789	13	HLH:				N = 203	N = 202	N = 187
	2	19.463	3.110	10	$\bar{X}$ = 21.712	HL*:	H*L:	*HL:			
	3	20.018	3.135	11	SD = 3.958						
	4	22.105	3.827	12	N = 46	$\bar{X}$ = 21.481	$\bar{X}$ = 20.823	$\bar{X}$ = 19.586			
						SD = 4.560	SD = 4.592	SD = 4.631			
HLL	1	20.582	6.803	13	HLL:	N = 96	N = 88	N = 103			
	2	22.863	3.964	11	$\bar{X}$ = 21.268						
	3	21.092	4.769	16	SD = 5.083						
	4	20.685	4.401	10	N = 50						
LHH	1	22.429	4.061	11	LHH:						
	2	19.911	3.067	13	$\bar{X}$ = 20.136	LH*:	L*H:	*LH:			
	3	17.749	6.090	10	SD = 4.643	$\bar{X}$ = 19.589	$\bar{X}$ = 21.647	$\bar{X}$ = 21.647			
	4	20.267	4.700	12	N = 46	SD = 4.805	SD = 4.186	SD = 4.186			
LHL	1	18.882	5.348	14	LHL:	N = 95	N = 88	N = 88			
	2	20.098	3.681	13	$\bar{X}$ = 19.076						
	3	18.337	5.239	12	SD = 4.943				L**:	*L*:	**L:
	4	18.906	5.922	10	N = 49				$\bar{X}$ = 20.187	$\bar{X}$ = 21.171	$\bar{X}$ = 20.140
LLH	1	21.909	4.457	11	LLH:				SD = 4.688	SD = 4.529	SD = 4.738
	2	23.933	3.284	11	$\bar{X}$ = 21.576	LL*:	L*L:	*LL:	N = 183	N = 184	N = 199
	3	20.945	3.845	9	SD = 4.468						
	4	19.402	5.253	11	N = 42	$\bar{X}$ = 20.833	$\bar{X}$ = 20.734	$\bar{X}$ = 20.734			
						SD = 4.496	SD = 4.803	SD = 4.803			
LLL	1	19.672	3.851	14	LLL:	N = 88	N = 96	N = 96			
	2	19.873	6.437	8	$\bar{X}$ = 20.154						
	3	20.458	4.846	12	SD = 4.462						
	4	20.600	3.660	12	N = 46						

TABLE 18

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Posttest, Lower-Order, Text-and-Teacher-as-Source Items, by Treatment (N=386 Pupils)

STR X SOL X REA X TCHR: TRMT	TCHR	$\bar{X}$	SD	N	STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH	1	5.977	1.068	13	HHH: $\bar{X}$ = 5.060; SD = 1.552; N = 53	HH*: $\bar{X}$ = 5.177; SD = 1.464; N = 107	H*H: $\bar{X}$ = 5.307; SD = 1.550; N = 99	*HH: $\bar{X}$ = 5.049; SD = 1.598; N = 99	H**: $\bar{X}$ = 5.408; SD = 1.544; N = 203	*H*: $\bar{X}$ = 5.112; SD = 1.574; N = 202	**H: $\bar{X}$ = 5.396; SD = 1.602; N = 187
	2	4.700	1.193	15							
	3	4.433	2.010	12							
	4	5.136	1.569	13							
HHL	1	5.607	1.081	14	HHL: $\bar{X}$ = 5.292; SD = 1.377; N = 54						
	2	5.806	1.157	12							
	3	4.090	1.701	15							
	4	4.712	1.310	13							
HLH	1	6.192	1.602	13	HLH: $\bar{X}$ = 5.593; SD = 1.514; N = 46	HL*: $\bar{X}$ = 5.665; SD = 1.598; N = 96	H*L: $\bar{X}$ = 5.495; SD = 1.661; N = 88	*HL: $\bar{X}$ 5.172; SD = 1.556; N = 103			
	2	5.713	1.106	10							
	3	4.958	1.464	11							
	4	5.427	1.662	12							
HLL	1	5.071	1.816	13	HLL: $\bar{X}$ = 5.732; SD = 1.683; N = 50						
	2	6.329	1.570	11							
	3	5.770	1.312	16							
	4	5.875	2.078	10							
LHH	1	5.021	1.573	11	LHH: $\bar{X}$ = 5.037; SD = 1.665; N = 46	LH*: $\bar{X}$ = 5.038; SD = 1.693; N = 95	L*H: $\bar{X}$ = 5.504; SD = 1.540; N = 104	*LH: $\bar{X}$ = 5.785; SD = 1.524; N = 88	L**: $\bar{X}$ = 5.314; SD = 1.678; N = 183	*L*: $\bar{X}$ = 5.640; SD = 1.604; N = 184	**L: $\bar{X}$ = 5.333; SD = 1.617; N = 199
	2	5.261	1.485	13							
	3	4.582	2.262	10							
	4	5.189	1.494	12							
LHL	1	4.935	2.059	14	LHL: $\bar{X}$ = 5.040; SD = 1.736; N = 49						
	2	5.142	1.574	13							
	3	5.458	1.742	12							
	4	4.551	1.548	10							
LLH	1	6.059	1.688	11	LLH: $\bar{X}$ = 5.996; SD = 1.523; N = 42	LL*: $\bar{X}$ = 5.612; SD = 1.619; N = 88	L*L: $\bar{X}$ = 5.147; SD = 1.685; N = 95	*LL: $\bar{X}$ = 5.506; SD = 1.671; N = 96			
	2	6.296	1.379	11							
	3	5.307	1.789	9							
	4	6.197	1.274	11							
LLL	1	4.991	1.931	14	LLL: $\bar{X}$ = 5.261; SD = 1.640; N = 46						
	2	4.776	1.375	8							
	3	5.545	1.781	12							
	4	5.617	1.314	12							

TABLE 19

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Posttest, Higher-Order, Text-and-Teacher-as-Source Items, by Treatment (N=386 Pupils)

STR X SOL X REA X TCHR: TRMT	TCHR	$\bar{X}$	SD	N	STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH	1	5.460	1.749	13	HHH:						
	2	5.393	2.106	15	$\bar{X}$ = 5.336	HH*:	H*H:	*HH:			
	3	5.922	1.055	12	SD = 1.729	$\bar{X}$ = 5.334	$\bar{X}$ = 5.493	$\bar{X}$ = 5.461			
	4	4.606	1.663	13	N = 53	SD = 1.725	SD = 1.571	SD = 1.715			
HHL	1	5.635	1.941	14	HHL:	N = 107	N = 99	N = 99			
	2	5.078	1.099	12	$\bar{X}$ = 5.331				H**:	*H*:	**H:
	3	5.247	2.045	15	SD = 1.737				$\bar{X}$ = 5.435	$\bar{X}$ = 5.372	$\bar{X}$ = 5.485
	4	5.335	1.754	13	N = 54				SD = 1.689	SD = 1.709	SD = 1.652
HLH	1	6.222	1.212	13	HLH:				N = 203	N = 202	N = 187
	2	4.798	1.447	10	$\bar{X}$ = 5.673	HL*:	H*L:	*HL:			
	3	5.359	1.253	11	SD = 1.363	$\bar{X}$ = 5.548	$\bar{X}$ = 5.477	$\bar{X}$ = 5.287			
	4	6.097	1.230	12	N = 46	SD = 1.650	SD = 1.748	SD = 1.707			
HLL	1	5.407	2.290	13	HLL:	N = 96	N = 88	N = 103			
	2	5.588	1.967	11	$\bar{X}$ = 5.433						
	3	5.515	1.670	16	SD = 1.882						
	4	5.165	1.793	10	N = 50						
LHH	1	6.922	0.985	11	LHH:						
	2	5.350	1.373	13	$\bar{X}$ = 5.605	LH*:	L*H:	*LH:			
	3	4.655	2.186	10	SD = 1.706	$\bar{X}$ = 5.416	$\bar{X}$ = 5.380	$\bar{X}$ = 5.513			
	4	5.465	1.550	12	N = 46	SD = 1.698	SD = 1.500	SD = 1.588			
LHL	1	5.252	2.007	14	LHL:	N = 95	N = 104	N = 88			
	2	5.291	1.559	13	$\bar{X}$ = 5.239				L**:	*L*:	**L:
	3	5.457	1.316	12	SD = 1.689				$\bar{X}$ = 5.392	$\bar{X}$ = 5.461	$\bar{X}$ = 5.348
	4	4.891	1.958	10	N = 49				SD = 1.698	SD = 1.676	SD = 1.729
LLH	1	4.828	1.841	11	LLH:				N = 183	N = 184	N = 199
	2	6.541	1.205	11	$\bar{X}$ = 5.338	LL*:	L*L:	*LL:			
	3	5.275	1.745	9	SD = 1.803	$\bar{X}$ = 5.366	$\bar{X}$ = 5.313	$\bar{X}$ = 5.413			
	4	4.694	1.926	11	N = 42	SD = 1.708	SD = 1.656	SD = 1.759			
LLL	1	5.345	2.036	14	LLL:	N = 88	N = 95	N = 96			
	2	4.886	1.661	8	$\bar{X}$ = 5.392						
	3	5.497	1.275	12	SD = 1.636						
	4	5.680	1.540	12	N = 46						

722

721

TABLE 20

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Posttest, Lower-Order, Teacher-Only-as-Source Items, By Treatment (N=386 Pupils)

STR X SOL X REA X TCHR: TRMT	TCHR	$\bar{X}$	SD	N	STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH	1	4.926	1.272	13	HHH: $\bar{X}$ = 4.747, SD = 1.579, N = 53	HH*: $\bar{X}$ = 4.687, SD = 1.496, N = 107	H*H: $\bar{X}$ = 4.569, SD = 1.492, N = 99	*HH: $\bar{X}$ = 4.981, SD = 1.632, N = 99	H**: $\bar{X}$ = 4.848, SD = 1.615, N = 203	*H*: $\bar{X}$ = 4.522, SD = 1.441, N = 202	**H: $\bar{X}$ = 4.793, SD = 1.521, N = 187
	2	4.948	1.347	15							
	3	3.701	1.846	12							
	4	5.303	1.561	13							
HHL	1	5.258	1.070	14	HHL: $\bar{X}$ = 4.629, SD = 1.422, N = 54						
	2	4.750	1.473	12							
	3	4.473	1.466	15							
	4	4.018	1.513	13							
HLH	1	6.153	1.452	13	HLH: $\bar{X}$ = 5.250, SD = 1.667, N = 46	HL*: $\bar{X}$ = 5.026, SD = 1.728, N = 96	H*L: $\bar{X}$ = 4.477, SD = 1.396, N = 103	*HL: $\bar{X}$ = 4.581, SD = 1.364, N = 98			
	2	4.535	1.048	10							
	3	4.605	1.675	11							
	4	5.458	1.909	12							
HLL	1	4.959	1.871	13	HLL: $\bar{X}$ = 4.820, SD = 1.773, N = 50						
	2	5.387	1.299	11							
	3	4.657	2.025	16							
	4	4.277	1.719	10							
LHH	1	4.880	1.365	11	LHH: $\bar{X}$ = 4.364, SD = 1.372, N = 46	LH*: $\bar{X}$ = 4.336, SD = 1.360, N = 95	L*H: $\bar{X}$ = 5.044, SD = 1.523, N = 88	*LH: $\bar{X}$ = 4.721, SD = 1.596, N = 104	L**: $\bar{X}$ = 4.537, SD = 1.393, N = 183	*L*: $\bar{X}$ = 4.896, SD = 1.582, N = 184	**L: $\bar{X}$ = 4.614, SD = 1.517, N = 199
	2	4.105	1.017	13							
	3	3.768	1.483	10							
	4	4.668	1.520	12							
LHL	1	4.330	1.042	14	LHL: $\bar{X}$ = 4.310, SD = 1.362, N = 49						
	2	4.527	1.027	13							
	3	3.923	1.986	12							
	4	4.462	1.344	10							
LLH	1	5.215	1.263	11	LLH: $\bar{X}$ = 4.819, SD = 1.331, N = 42	LL*: $\bar{X}$ = 4.755, SD = 1.402, N = 88	L*L: $\bar{X}$ = 4.761, SD = 1.630, N = 96	*LL: $\bar{X}$ = 4.497, SD = 1.424, N = 95			
	2	4.791	1.347	11							
	3	4.916	1.348	9							
	4	4.370	1.414	11							
LLL	1	4.492	1.734	14	LLL: $\bar{X}$ = 4.696, SD = 1.477, N = 46						
	2	4.678	1.824	8							
	3	4.606	1.324	12							
	4	5.037	1.143	12							

541

TABLE 21

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Posttest, Higher-Order, Teacher-Only-as-Source Items, by Treatment (N=386 Pupils)

STR X SOL X REA X TCHR					STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
TRMT	TCHR	$\bar{X}$	SD	N							
HHH	1	4.636	1.663	13	HHH:						
	2	4.511	2.094	15	$\bar{X}$ = 4.645	HH*:	H*H:	*HH:			
	3	4.521	1.331	12	SD = 1.679						
	4	4.925	1.607	13	N = 53	$\bar{X}$ = 4.722	$\bar{X}$ = 4.901	$\bar{X}$ = 4.870			
						SD = 1.649	SD = 1.560	SD = 1.752			
HHL	1	4.428	1.668	14	HHL:	N = 107	N = 99	N = 99			
	2	4.852	1.043	12	$\bar{X}$ = 4.797				H**:	*H*:	**H:
	3	4.565	1.881	15	SD = 1.632						
	4	5.411	1.727	13	N = 54				$\bar{X}$ = 4.967	$\bar{X}$ = 4.758	$\bar{X}$ = 5.075
									SD = 1.575	SD = 1.740	SD = 1.701
HLH	1	5.948	0.900	13	HLH:				N = 203	N = 202	N = 187
	2	4.417	1.354	10	$\bar{X}$ = 5.196	HL*:	H*L:	*HL:			
	3	5.096	1.719	11	SD = 1.370						
	4	5.124	1.173	12	N = 46	$\bar{X}$ = 5.241	$\bar{X}$ = 5.270	$\bar{X}$ = 4.650			
						SD = 1.447	SD = 1.836	SD = 1.731			
HLL	1	5.146	2.090	13	HLL:	N = 96	N = 88	N = 103			
	2	5.560	0.946	11	$\bar{X}$ = 5.283						
	3	5.151	1.651	16	SD = 1.527						
	4	5.367	1.086	10	N = 50						
LHH	1	5.605	2.138	11	LHH:						
	2	5.194	1.304	13	$\bar{X}$ = 5.130	LH*:	L*H:	*LH:			
	3	4.743	2.058	10	SD = 1.815						
	4	4.946	1.898	12	N = 46	$\bar{X}$ = 4.799	$\bar{X}$ = 5.030	$\bar{X}$ = 5.305			
						SD = 1.845	SD = 1.594	SD = 1.621			
LHL	1	4.366	2.044	14	LHL:	N = 95	N = 104	N = 88			
	2	5.137	1.576	13	$\bar{X}$ = 4.488						
	3	3.499	1.227	12	SD = 1.837				L**:	*L*:	**L:
	4	5.001	2.138	10	N = 49				$\bar{X}$ = 4.944	$\bar{X}$ = 5.174	$\bar{X}$ = 4.845
									SD = 1.869	SD = 1.672	SD = 1.731
LLH	1	5.806	1.840	11	LLH:				N = 183	N = 184	N = 199
	2	6.304	1.285	11	$\bar{X}$ = 5.423	LL*:	L*L:	*LL:			
	3	5.447	1.519	9	SD = 1.868						
	4	4.141	2.143	11	N = 42	$\bar{X}$ = 5.100	$\bar{X}$ = 4.641	$\bar{X}$ = 5.054			
						SD = 1.892	SD = 1.858	SD = 1.717			
LLL	1	4.845	2.212	14	LLL:	N = 88	N = 95	N = 96			
	2	5.534	2.298	8	$\bar{X}$ = 4.805						
	3	4.810	1.576	12	SD = 1.887						
	4	4.266	1.493	12	N = 46						

TABLE 22

Means and Standard Deviations of Adjusted Log Transformations of Essay Posttest Scores, by Treatment (N=385 Pupils)

TRMT	TCHR	$\bar{X}$	SD	N	STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH	1	0.384	0.160	13	HHH: $\bar{X}$ = 0.325, SD = 0.261, N = 53	HH*: $\bar{X}$ = 0.338, SD = 0.246, N = 107	H*H: $\bar{X}$ = 0.335, SD = 0.264, N = 99	*HH: $\bar{X}$ = 0.362, SD = 0.245, N = 99	H**: $\bar{X}$ = 0.344, SD = 0.244, N = 203	*H*: $\bar{X}$ = 0.352, SD = 0.253, N = 202	**H: $\bar{X}$ = 0.379, SD = 0.249, N = 187
	2	0.233	0.262	15							
	3	0.241	0.194	12							
	4	0.450	0.343	13							
HHL	1	0.437	0.248	14	HHL: $\bar{X}$ = 0.350, SD = 0.232, N = 54						
	2	0.294	0.233	12							
	3	0.252	0.225	15							
	4	0.421	0.183	13							
HLH	1	0.640	0.147	13	HLH: $\bar{X}$ = 0.347, SD = 0.269, N = 46	HL*: $\bar{X}$ = 0.351, SD = 0.243, N = 96	H*L: $\bar{X}$ = 0.429, SD = 0.223, N = 88	*HL: $\bar{X}$ = 0.342, SD = 0.262, N = 103			
	2	0.203	0.224	10							
	3	0.267	0.191	11							
	4	0.223	0.233	12							
HLL	1	0.249	0.199	13	HLL: $\bar{X}$ = 0.355, SD = 0.219, N = 50						
	2	0.480	0.181	11							
	3	0.327	0.205	16							
	4	0.399	0.249	10							
LHH	1	0.371	0.271	11	LHH: $\bar{X}$ = 0.404, SD = 0.219, N = 46	LH*: $\bar{X}$ = 0.368, SD = 0.261, N = 95	L*H: $\bar{X}$ = 0.352, SD = 0.225, N = 104	*LH: $\bar{X}$ = 0.399, SD = 0.254, N = 88	L**: $\bar{X}$ = 0.381, SD = 0.248, N = 182	*L*: $\bar{X}$ = 0.372, SD = 0.239, N = 183	**L: $\bar{X}$ = 0.345, SD = 0.243, N = 198
	2	0.428	0.218	13							
	3	0.394	0.206	10							
	4	0.418	0.203	12							
LHL	1	0.26[illegible]	0.284	14	LHL: $\bar{X}$ = 0.334, SD = 0.293, N = 49						
	2	0.464	0.367	13							
	3	0.351	0.246	12							
	4	0.245	0.213	10							
LLH	1	0.442	0.183	11	LLH: $\bar{X}$ = 0.455, SD = 0.227, N = 42	LL*: $\bar{X}$ = 0.395, SD = 0.233, N = 87	L*L: $\bar{X}$ = 0.336, SD = 0.262, N = 94	*LL: $\bar{X}$ = 0.347, SD = 0.221, N = 95			
	2	0.474	0.175	11							
	3	0.372	0.276	9							
	4	0.519	0.274	11							
LLL	1	0.379	0.243	14	LLL: $\bar{X}$ = 0.339, SD = 0.227, N = 45						
	2	0.354	0.277	8							
	3	0.213	0.197	11							
	4	0.397	0.174	12							

543

TABLE 23

Means and Standard Deviations of Adjusted Attitude-toward-Ecology Posttest Scores, by Treatment (N=385 Pupils)

STR X SOL X REA X TCHR					STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
TRMT	TCHR	X̄	SD	N							
HHH	1	44.091	5.883	13	HHH: X̄ = 43.023 SD = 5.631 N = 53	HH*: X̄ = 43.131 SD = 5.660 N = 107	H*H: X̄ = 42.520 SD = 5.412 N = 98	*HH: X̄ = 43.095 SD = 5.626 N = 99	H**: X̄ = 42.634 SD = 6.240 N = 202	*H*: X̄ = 42.819 SD = 5.911 N = 202	**H: X̄ = 43.045 SD = 5.876 N = 186
	2	41.571	5.486	15							
	3	42.952	4.354	12							
	4	43.697	6.778	13							
HHL	1	44.282	4.688	14	HHL: X̄ = 43.237 SD = 5.739 N = 54						
	2	44.589	4.162	12							
	3	42.065	6.452	15							
	4	42.215	7.158	13							
HLH	1	41.783	4.588	13	HLH: X̄ = 41.928 SD = 5.144 N = 45	HL*: X̄ = 42.075 SD = 6.821 N = 95	H*L: X̄ = 43.629 SD = 6.333 N = 88	*HL: X̄ = 42.554 SD = 6.188 N = 103			
	2	43.097	3.414	9							
	3	39.025	6.562	11							
	4	43.871	4.535	12							
HLL	1	43.774	5.075	13	HLL: X̄ = 42.206 SD = 8.091 N = 50						
	2	45.042	7.430	11							
	3	38.807	10.896	16							
	4	42.490	5.369	10							
LHH	1	44.055	7.179	11	LHH: X̄ = 43.178 SD = 5.683 N = 46	LH*: X̄ = 42.468 SD = 6.194 N = 95	L*H: X̄ = 42.741 SD = 6.954 N = 104	*LH: X̄ = 42.988 SD = 6.181 N = 87	L**: X̄ = 42.943 SD = 6.192 N = 183	*L*: X̄ = 42.739 SD = 6.540 N = 183	**L: X̄ = 42.534 SD = 6.511 N = 199
	2	41.883	6.304	13							
	3	42.432	4.343	10							
	4	44.398	4.648	12							
LHL	1	39.752	7.080	14	LHL: X̄ = 41.801 SD = 6.194 N = 49						
	2	43.458	4.094	13							
	3	43.777	7.691	12							
	4	40.145	6.962	10							
LLH	1	39.852	6.271	11	LLH: X̄ = 44.123 SD = 7.015 N = 42	LL*: X̄ = 43.456 SD = 6.182 N = 88	L*L: X̄ = 42.308 SD = 6.019 N = 95	*LL: X̄ = 42.514 SD = 6.874 N = 96			
	2	42.429	5.594	11							
	3	51.115	6.519	9							
	4	44.368	5.463	11							
LLL	1	40.499	5.013	14	LLL: X̄ = 42.847 SD = 5.317 N = 46						
	2	43.474	4.340	8							
	3	41.933	5.125	12							
	4	46.083	5.297	12							

TABLE 24

Means and Standard Deviations of Adjusted Total Scores on the Multiple-Choice Achievement Retention Test, by Treatment (N=386 Pupils)

STR X SOL X REA X TCHR					STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
TRMT	TCHR	$\bar{X}$	SD	N							
HHH	1	19.704	2.820	13	HHH: $\bar{X}$ = 18.282 SD = 5.243 N = 53	HH*: $\bar{X}$ = 18.870 SD = 5.429 N = 107	H*H: $\bar{X}$ = 19.347 SD = 4.757 N = 99	*HH: $\bar{X}$ = 18.662 SD = 4.852 N = 99	H**: $\bar{X}$ = 19.305 SD = 5.211 N = 203	*H*: $\bar{X}$ = 18.463 SD = 5.301 N = 202	**H: $\bar{X}$ = 19.444 SD = 4.475 N = 187
	2	18.838	6.095	15							
	3	17.672	5.860	12							
	4	16.782	5.564	13							
HHL	1	21.499	4.079	14	HHL: $\bar{X}$ = 19.448 SD = 5.594 N = 54						
	2	20.666	3.844	12							
	3	16.189	7.606	15							
	4	19.875	4.391	13							
HLH	1	21.724	2.844	13	HLH: $\bar{X}$ = 20.575 SD = 3.825 N = 46	HL*: $\bar{X}$ = 19.790 SD = 4.940 N = 96	H*L: $\bar{X}$ = 19.553 SD = 4.160 N = 88	*HL: $\bar{X}$ = 18.271 SD = 5.716 N = 103			
	2	20.574	3.930	10							
	3	17.840	4.229	11							
	4	21.838	3.368	12							
HLL	1	18.266	6.217	13	HLL: $\bar{X}$ = 19.068 SD = 5.724 N = 50						
	2	21.412	4.454	11							
	3	17.669	6.324	16							
	4	19.768	5.146	10							
LHH	1	21.497	3.288	11	LHH: $\bar{X}$ = 19.100 SD = 4.375 N = 46	LH*: $\bar{X}$ = 18.003 SD = 5.142 N = 95	L*H: $\bar{X}$ = 19.265 SD = 5.633 N = 104	*LH: $\bar{X}$ = 20.323 SD = 3.849 N = 88	L**: $\bar{X}$ = 18.434 SD = 4.936 N = 183	*L*: $\bar{X}$ = 19.364 SD = 4.829 N = 184	**L: $\bar{X}$ = 18.374 SD = 5.577 N = 199
	2	20.393	4.069	13							
	3	16.869	5.288	10							
	4	17.363	3.463	12							
LHL	1	16.382	4.256	14	LHL: $\bar{X}$ = 16.974 SD = 5.621 N = 49						
	2	18.321	5.488	13							
	3	17.593	6.511	12							
	4	15.308	6.604	10							
LLH	1	17.399	3.912	11	LLH: $\bar{X}$ = 20.048 SD = 3.902 N = 42	LL*: $\bar{X}$ = 18.899 SD = 4.689 N = 88	L*L: $\bar{X}$ = 17.398 SD = 5.377 N = 95	*LL: $\bar{X}$ = 18.484 SD = 5.452 N = 96			
	2	22.499	2.273	11							
	3	20.550	2.490	9							
	4	19.835	4.731	11							
LLL	1	17.666	4.687	14	LLL: $\bar{X}$ = 17.850 SD = 5.127 N = 46						
	2	18.019	6.513	8							
	3	16.402	6.003	12							
	4	19.400	3.683	12							

545

TABLE 25

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Retention Test, Lower-Order, Text-and-Teacher-as-Source Items, by Treatment (N=386 Pupils)

STR X SOL X REA X TCHR					STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
TRMT	TCHR	$\bar{X}$	SD	N							
HHH	1	4.909	0.779	13	HHH: $\bar{X}$ = 4.320 SD = 1.397 N = 53	HH*: $\bar{X}$ = 4.582 SD = 1.594 N = 107	H*H: $\bar{X}$ = 4.737 SD = 1.524 N = 99	*HH: $\bar{X}$ = 4.629 SD = 1.475 N = 99	H**: $\bar{X}$ = 4.795 SD = 1.633 N = 203	*H*: $\bar{X}$ = 4.658 SD = 1.717 N = 202	**H: $\bar{X}$ = 4.874 SD = 1.496 N = 187
	2	4.081	1.340	15							
	3	4.134	1.228	12							
	4	4.178	1.966	13							
HHL	1	5.370	1.476	14	HHL: $\bar{X}$ = 4.839 SD = 1.742 N = 54						
	2	5.231	1.423	12							
	3	4.070	2.180	15							
	4	4.793	1.554	13							
HLH	1	5.473	1.105	13	HLH: $\bar{X}$ = 5.218 SD = 1.537 N = 46	HL*: $\bar{X}$ = 5.033 SD = 1.650 N = 96	H*L: $\bar{X}$ = 5.027 SD = 1.457 N = 88	*HL: $\bar{X}$ = 4.686 SD = 1.927 N = 103			
	2	5.653	1.824	10							
	3	4.022	1.486	11							
	4	5.676	1.302	12							
HLL	1	4.396	1.671	13	HLL: $\bar{X}$ = 4.863 SD = 1.746 N = 50						
	2	5.597	1.383	11							
	3	4.485	1.883	16							
	4	5.270	1.853	10							
LHH	1	5.431	1.553	11	LHH: $\bar{X}$ = 4.986 SD = 1.497 N = 46	LH*: $\bar{X}$ = 4.744 SD = 1.849 N = 95	L*H: $\bar{X}$ = 4.851 SD = 1.736 N = 104	*LH: $\bar{X}$ = 5.148 SD = 1.480 N = 88	L**: $\bar{X}$ = 4.780 SD = 1.675 N = 183	*L*: $\bar{X}$ = 4.931 SD = 1.568 N = 184	**L: $\bar{X}$ = 4.708 SD = 1.785 N = 199
	2	4.960	1.659	13							
	3	4.920	1.732	10							
	4	4.662	1.097	12							
LHL	1	3.882	1.791	14	LHL: $\bar{X}$ = 4.516 SD = 2.118 N = 49						
	2	5.293	2.043	13							
	3	4.912	1.845	12							
	4	3.920	2.732	10							
LLH	1	4.218	1.543	11	LLH: $\bar{X}$ = 5.072 SD = 1.428 N = 42	LL*: $\bar{X}$ = 4.819 SD = 1.475 N = 88	L*L: $\bar{X}$ = 4.551 SD = 1.833 N = 95	*LL: $\bar{X}$ = 4.731 SD = 1.628 N = 96			
	2	5.552	1.132	11							
	3	5.018	1.335	9							
	4	5.491	1.424	11							
LLL	1	4.703	1.633	14	LLL: $\bar{X}$ = 4.587 SD = 1.494 N = 46						
	2	3.954	1.548	8							
	3	4.523	1.741	12							
	4	4.940	0.983	12							

TABLE 26

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Retention Test, Higher-Order, Text-and-Teacher-as-Source Items, by Treatment (N=386 Pupils)

STR X SOL X REA X TCHR					STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
TRMT	TCHR	$\bar{X}$	SD	N							
HHH	1	4.795	1.392	13	HHH:						
	2	5.494	2.040	15	$\bar{X}$ = 5.112	HH*:	H*H:	*HH:			
	3	5.804	2.160	12	SD = 1.900						
	4	4.350	1.780	13	N = 53	$\bar{X}$ = 5.201	$\bar{X}$ = 4.737	$\bar{X}$ = 5.188			
						SD = 1.940	SD = 1.524	SD = 1.844			
HHL	1	6.190	1.732	14	HHL:	N = 107	N = 99	N = 99			
	2	5.941	1.651	12	$\bar{X}$ = 5.288				H**:	*H*:	**H:
	3	4.280	2.212	15	SD = 1.992				$\bar{X}$ = 5.295	$\bar{X}$ = 5.101	$\bar{X}$ = 4.874
	4	4.877	1.801	13	N = 54				SD = 1.790	SD = 1.908	SD = 1.496
									N = 203	N = 202	N = 187
HLH	1	5.686	1.273	13	HLH:						
	2	5.355	1.311	10	$\bar{X}$ = 5.622	HL*:	H*L:	*HL:			
	3	5.158	1.715	11	SD = 1.353						
	4	6.203	0.990	12	N = 46	$\bar{X}$ = 5.400	$\bar{X}$ = 5.027	$\bar{X}$ = 5.017			
						SD = 1.610	SD = 1.457	SD = 1.973			
HLL	1	5.321	1.992	13	HLL:	N = 96	N = 88	N = 103			
	2	5.468	2.049	11	$\bar{X}$ = 5.195						
	3	5.115	1.623	16	SD = 1.804						
	4	4.862	1.768	10	N = 50						
LHH	1	6.293	1.194	11	LHH:						
	2	5.509	1.767	13	$\bar{X}$ = 5.276	LH*:	L*H:	*LH:			
	3	4.183	1.956	10	SD = 1.795						
	4	5.005	1.756	12	N = 46	$\bar{X}$ = 4.989	$\bar{X}$ = 4.851	$\bar{X}$ = 5.405			
						SD = 1.876	SD = 1.736	SD = 1.502			
LHL	1	4.388	1.633	14	LHL:	N = 95	N = 104	N = 88			
	2	4.981	1.788	13	$\bar{X}$ = 4.719						
	3	5.364	2.396	12	SD = 1.928				L**:	*L*:	**L:
	4	4.069	1.844	10	N = 49				$\bar{X}$ = 5.028	$\bar{X}$ = 5.242	$\bar{X}$ = 4.708
									SD = 1.776	SD = 1.644	SD = 1.785
LLH	1	4.060	2.052	11	LLH:				N = 183	N = 184	N = 199
	2	6.009	0.912	11	$\bar{X}$ = 5.168	LL*:	L*L:	*LL:			
	3	5.165	1.440	9	SD = 1.634						
	4	5.437	1.427	11	N = 42	$\bar{X}$ = 5.069	$\bar{X}$ = 4.551	$\bar{X}$ = 5.092			
						SD = 1.672	SD = 1.833	SD = 1.758			
LLL	1	5.129	1.943	14	LLL:	N = 88	N = 95	N = 96			
	2	5.209	2.259	8	$\bar{X}$ = 4.979						
	3	4.624	1.538	12	SD = 1.719						
	4	5.006	1.348	12	N = 46						

TABLE 27

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Retention Test, Lower Order, Teacher-Only-as-Source Items, by Treatment (N=386 Pupils)

STR X SOL X REA X TCHR					STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
TRMT	TCHR	$\bar{X}$	SD	N							
HHH	1	4.818	1.631	13	HHH:						
	2	4.370	2.212	15	$\bar{X}$ = 4.341	HH*:	H*H:	*HH:			
	3	3.679	1.580	12	SD = 1.774						
	4	4.441	1.511	13	N = 53	$\bar{X}$ = 4.363	$\bar{X}$ = 4.466	$\bar{X}$ = 4.081			
						SD = 1.741	SD = 1.707	SD = 1.587			
HHL	1	4.819	1.568	14	HHL:	N = 107	N = 99	N = 99			
	2	4.634	1.763	12	$\bar{X}$ = 4.384				H**:	*H*:	**H:
	3	3.627	2.053	15	SD = 1.725				$\bar{X}$ = 4.387	$\bar{X}$ = 4.018	$\bar{X}$ = 4.294
	4	4.559	1.299	13	N = 54				SD = 1.741	SD = 1.629	SD = 1.543
HLH	1	4.954	1.487	13	HLH:				N = 203	N = 202	N = 187
	2	4.309	1.788	10	$\bar{X}$ = 4.610	HL*:	H*L:	*HL:			
	3	4.502	1.677	11	SD = 1.634						
	4	4.587	1.762	12	N = 46	$\bar{X}$ = 4.414	$\bar{X}$ = 4.100	$\bar{X}$ = 3.958			
						SD = 1.748	SD = 1.319	SD = 1.674			
HLL	1	3.693	1.814	13	HLL:	N = 96	N = 88	N = 103			
	2	5.062	1.311	11	$\bar{X}$ = 4.234						
	3	4.017	2.021	16	SD = 1.845						
	4	4.375	2.018	10	N = 50						
LHH	1	4.213	0.951	11	LHH:						
	2	3.954	1.363	13	$\bar{X}$ = 3.781	LH*:	L*H:	*LH:			
	3	3.485	1.389	10	SD = 1.295	$\bar{X}$ = 3.629	$\bar{X}$ = 4.312	$\bar{X}$ = 4.534			
	4	3.443	1.414	12	N = 46	SD = 1.402	SD = 1.777	SD = 1.465			
LHL	1	3.584	1.280	14	LHL:	N = 95	N = 104	N = 88			
	2	3.757	1.740	13	$\bar{X}$ = 3.488						
	3	3.782	1.461	12	SD = 1.496				L**:	*L*:	**L:
	4	2.649	1.383	10	N = 49				$\bar{X}$ = 3.867	$\bar{X}$ = 4.275	$\bar{X}$ = 3.997
LLH	1	4.064	1.521	11	LLH:				SD = 1.466	SD = 1.635	SD = 1.708
	2	4.743	1.148	11	$\bar{X}$ = 4.450	LL*:	L*L:	*LL:	N = 183	N = 184	N = 199
	3	4.763	1.256	9	SD = 1.268	$\bar{X}$ = 4.124	$\bar{X}$ = 3.652	$\bar{X}$ = 4.039			
	4	4.289	1.153	11	N = 42	SD = 1.497	SD = 1.567	SD = 1.751			
LLL	1	3.348	1.441	14	LLL:	N = 88	N = 95	N = 96			
	2	3.896	1.863	8	$\bar{X}$ = 3.827						
	3	3.383	1.629	12	SD = 1.637						
	4	4.782	1.461	12	N = 46						

TABLE 28

Means and Standard Deviations of Adjusted Scores on the Multiple-Choice Achievement Retention Test, Higher-Order, Teacher-Only-as-Source Items, by Treatment (N=386 Pupils)

TRMT	TCHR	$\bar{X}$	SD	N	STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
HHH	1	5.182	1.290	13	HHH:						
	2	4.893	1.834	15	$\bar{X}$ = 4.509	HH*:	H*H:	*HH:			
	3	4.055	2.279	12	SD = 1.808						
	4	3.812	1.551	13	N = 53	$\bar{X}$ = 4.725	$\bar{X}$ = 4.795	$\bar{X}$ = 4.764			
						SD = 1.771	SD = 1.656	SD = 1.823			
HHL	1	5.120	1.206	14	HHL:	N = 107	N = 99	N = 99			
	2	4.860	1.244	12	$\bar{X}$ = 4.936				H**:	*H*:	**H:
	3	4.212	2.298	15	SD = 1.725						
	4	5.646	1.654	13	N = 54				$\bar{X}$ = 4.828	$\bar{X}$ = 4.685	$\bar{X}$ = 4.986
									SD = 1.719	SD = 1.805	SD = 1.656
HLH	1	5.612	1.256	13	HLH:				N = 203	N = 202	N = 187
	2	5.257	1.370	10	$\bar{X}$ = 5.125	HL*:	H*L:	*HL:			
	3	4.159	1.564	11	SD = 1.409						
	4	5.372	1.161	12	N = 46	$\bar{X}$ = 4.942	$\bar{X}$ = 4.859	$\bar{X}$ = 4.610			
						SD = 1.661	SD = 1.785	SD = 1.793			
HLL	1	4.856	1.789	13	HLL:	N = 96	N = 104	N = 103			
	2	5.284	1.759	11	$\bar{X}$ = 4.774						
	3	4.053	2.046	16	SD = 1.861						
	4	5.262	1.629	10	N = 50						
LHH	1	5.561	1.488	11	LHH:						
	2	5.970	1.281	13	$\bar{X}$ = 5.057	LH*:	L*H:	*LH:			
	3	4.281	2.100	10	SD = 1.816						
	4	4.253	1.895	12	N = 46	$\bar{X}$ = 4.641	$\bar{X}$ = 5.200	$\bar{X}$ = 5.236			
						SD = 1.851	SD = 1.639	SD = 1.414			
LHL	1	4.528	1.432	14	LHL:	N = 95	N = 88	N = 88			
	2	4.289	1.756	13	$\bar{X}$ = 4.250						
	3	3.535	1.940	12	SD = 1.815				L**:	*L*:	**L:
	4	4.670	2.213	10	N = 49				$\bar{X}$ = 4.759	$\bar{X}$ = 4.916	$\bar{X}$ = 4.616
									SD = 1.810	SD = 1.708	SD = 1.840
LLH	1	5.057	1.281	11	LLH:				N = 183	N = 184	N = 199
	2	6.195	0.854	11	$\bar{X}$ = 5.357	LL*:	L*L:	*LL:			
	3	5.604	1.571	9	SD = 1.425						
	4	4.618	1.567	11	N = 42	$\bar{X}$ = 4.887	$\bar{X}$ = 4.350	$\bar{X}$ = 4.622			
						SD = 1.767	SD = 1.873	SD = 1.900			
LLL	1	4.486	1.442	14	LLL:	N = 88	N = 95	N = 96			
	2	4.961	2.164	8	$\bar{X}$ = 4.457						
	3	3.872	2.686	12	SD = 1.948						
	4	4.673	1.501	12	N = 46						

TABLE 29
Means and Standard Deviations of Adjusted Log Transformations of Essay Retention Test Scores, by Treatment (N=386 Pupils)

STR X SOL X REA X TCHR					STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
TRMT	TCHR	X̄	SD	N							
HHH	1	0.230	0.219	13	HHH: X̄ = 0.220 SD = 0.268 N = 53	HH*: X̄ = 0.181 SD = 0.232 N = 107	H*H: X̄ = 0.265 SD = 0.282 N = 99	*HH: X̄ = 0.224 SD = 0.268 N = 99			
	2	0.216	0.290	15							
	3	0.154	0.201	12							
	4	0.277	0.346	13							
HHL	1	0.216	0.180	14	HHL: X̄ = 0.142 SD = 0.136 N = 54				H**: X̄ = 0.223 SD = 0.250 N = 203	*H*: X̄ = 0.189 SD = 0.235 N = 202	**H: X̄ = 0.261 SD = 0.275 N = 187
	2	0.126	0.225	12							
	3	0.065	0.132	15							
	4	0.168	0.189	13							
HLH	1	0.498	0.241	13	HLH: X̄ = 0.316 SD = 0.2[illegible] N = 46	HL*: X̄ = 0.270 SD = 0.261 N = 96	H*L: X̄ = 0.257 SD = 0.268 N = 88	*HL: X̄ = 0.155 SD = 0.195 N = 103			
	2	0.146	0.255	10							
	3	0.111	0.186	11							
	4	0.449	0.268	12							
HLL	1	0.189	0.220	13	HLL: X̄ = 0.228 SD = 0.226 N = 50						
	2	0.413	0.264	11							
	3	0.222	0.164	16							
	4	0.088	0.158	10							
LHH	1	0.256	0.331	11	LHH: X̄ = 0.227 SD = 0.226 N = 50	LH*: X̄ = 0.197 SD = 0.239 N = 95	L*H: X̄ = 0.184 SD = 0.209 N = 104	*LH: X̄ = 0.304 SD = 0.27[illegible] N = 88			
	2	0.150	0.242	13							
	3	0.348	0.289	10							
	4	0.185	0.207	12							
LHL	1	0.172	0.186	14	LHL: X̄ = 0.169 SD = 0.205 N = 49				L**: X̄ = 0.204 SD = 0.246 N = 183	*L*: X̄ = 0.242 SD = 0.259 N = 184	**L: X̄ = 0.170 SD = 0.211 N = 199
	2	0.161	0.168	13							
	3	0.241	0.265	12							
	4	0.092	0.195	10							
LLH	1	0.227	0.273	11	LLH: X̄ = 0.290 SD = 0.266 N = 42	LL*: X̄ = 0.212 SD = 0.253 N = 38	L*L: X̄ = 0.156 SD = 0.213 N = 95	*LL: X̄ = 0.186 SD = 0.227 N = 96			
	2	0.469	0.262	11							
	3	0.269	0.183	9							
	4	0.189	0.261	11							
LLL	1	0.067	0.190	14	LLL: X̄ = 0.141 SD = 0.221 N = 46						
	2	0.074	0.133	8							
	3	0.083	0.158	12							
	4	0.329	0.262	12							

TABLE 30

Means and Standard Deviations of Adjusted Attitude-toward-Ecology Retention Test Scores, by Treatment (N=384 Pupils)

STR X SOL X REA X TCHR					STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
TRMT	TCHR	$\bar{X}$	SD	N							
HHH	1	42.591	5.952	13	HHH:						
	2	38.506	5.309	15	$\bar{X}$ = 39.995	HH*:	H*H:	*HH:			
	3	39.433	5.108	12	SD = 6.386						
	4	39.637	8.601	13	N = 53	$\bar{X}$ = 40.659	$\bar{X}$ = 40.315	$\bar{X}$ = 40.523			
						SD = 6.038	SD = 6.862	SD = 6.878			
HHL	1	42.626	4.605	14	HHL:	N = 106	N = 99	N = 99			
	2	43.168	3.645	11	$\bar{X}$ = 41.324				H**:	*H*:	**H:
	3	39.098	5.502	15	SD = 5.651						
	4	40.928	7.586	13	N = 53				$\bar{X}$ = 40.467	$\bar{X}$ = 40.614	$\bar{X}$ = 40.607
									SD = 7.275	SD = 6.708	SD = 7.066
									N = 202	N = 200	N = 187
HLH	1	41.530	7.929	13	HLH:						
	2	41.742	7.806	10	$\bar{X}$ = 40.684	HL*:	H*L:	*HL:			
	3	38.246	8.629	11	SD = 7.429						
	4	41.121	5.623	12	N = 46	$\bar{X}$ = 40.254	$\bar{X}$ = 40.935	$\bar{X}$ = 40.702			
						SD = 8.461	SD = 7.315	SD = 6.571			
HLL	1	42.037	6.070	13	HLL:	N = 96	N = 88	N = 101			
	2	41.583	9.225	11	$\bar{X}$ = 39.859						
	3	37.375	12.812	16	SD = 9.370						
	4	39.104	6.215	10	N = 50						
LHH	1	42.386	10.628	11	LHH:						
	2	39.150	3.695	13	$\bar{X}$ = 41.131	LH*:	L*H:	*LH:			
	3	40.151	9.[illegible]	10	SD = 7.431						
	4	42.948	5.340	12	N = 46	$\bar{X}$ = 40.562	$\bar{X}$ = 40.612	$\bar{X}$ = 40.701			
						SD = 7.427	SD = 7.680	SD = 7.311			
LHL	1	38.593	8.589	14	LHL:	N = 94	N = 103	N = 88			
	2	40.411	4.797	12	$\bar{X}$ = 40.016						
	3	41.754	9.503	12	SD = 7.460				L**:	*L*:	**L:
	4	39.451	6.152	10	N = 48				$\bar{X}$ = 40.703	$\bar{X}$ = 40.541	$\bar{X}$ = 40.552
LLH	1	38.514	6.640	11	LLH:				SD = 7.071	SD = 7.658	SD = 7.284
	2	39.730	7.414	11	$\bar{X}$ = 4.719	LL*:	L*L:	*LL:	N = 182	N = 184	N = 197
	3	45.267	6.548	9	SD = 7.272						
	4	40.195	7.622	11	N = 42	$\bar{X}$ = 40.854	$\bar{X}$ = 40.486	$\bar{X}$ = 40.394			
						SD = 6.709	SD = 6.864	SD = 7.998			
LLL	1	38.287	5.787	14	LLL:	N = 88	N = 94	N = 96			
	2	38.893	4.747	8	$\bar{X}$ = 40.977						
	3	40.470	4.288	12	SD = 6.229						
	4	46.011	6.792	12	N = 46						

TABLE 31

Means and Standard Deviations of Adjusted Scores on the True-False-? Retention Test, by Treatment (N-384 Pupils)

STR X SOL X REA X TCHR					STR X SOL X REA	STR X SOL	STR X REA	SOL X REA	STR	SOL	REA
TRMT	TCHR	$\bar{X}$	SD	N							
HHH	1	12.975	3.102	3	HHH: $\bar{X}$ = 11.345 SD = 3.197 N = 53						
	2	10.467	2.837	15							
	3	10.566	3.741	12		HH*: $\bar{X}$ = 11.517 SD = 3.107 N = 107	H*H: $\bar{X}$ = 11.770 SD = 2.681 N = 99	*HH: $\bar{X}$ = 11.475 SD = 2.997 N = 99			
	4	11.448	2.826	13							
HHL	1	12.114	2.605	14	HHL: $\bar{X}$ = 11.686 SD = 3.037 N = 54						
	2	12.943	2.117	12							
	3	9.563	2.553	15					H**: $\bar{X}$ = 11.647 SD = 2.856 N = 203	*H*: $\bar{X}$ = 11.545 SD = 2.985 N = 200	**H: $\bar{X}$ = 11.576 SD = 2.685 N = 187
	4	12.515	3.676	13							
HLH	1	13.225	2.211	13	HLH: $\bar{X}$ = 12.259 SD = 1.841 N = 46						
	2	12.095	1.161	10		HL*: $\bar{X}$ = 11.791 SD = 2.555 N = 96	H*L: $\bar{X}$ = 11.530 SD = 3.021 N = 104	*HL: $\bar{X}$ = 11.614 SD = 2.987 N = 101			
	3	11.321	2.152	11							
	4	12.209	1.298	12							
HLL	1	11.084	3.847	13	HLL: $\bar{X}$ = 11.361 SD = 3.025 N = 50						
	2	11.125	3.447	11							
	3	12.027	2.345	16							
	4	10.916	2.556	10							
LHH	1	12.049	2.428	11	LHH: $\bar{X}$ = 11.624 SD = 2.776 N = 46						
	2	12.090	2.590	13							
	3	10.811	3.328	10		LH*: $\bar{X}$ = 11.587 SD = 2.855 N = 93	L*H: $\bar{X}$ = 11.357 SD = 2.687 N = 88	*LH: $\bar{X}$ = 11.689 SD = 2.295 N = 88			
	4	11.407	22947	12							
LHL	1	9.905	2.516	14	LHL: $\bar{X}$ = 11.533 SD = 2.959 N = 47						
	2	12.179	2.358	12							
	3	13.528	3.030	12					L**: $\bar{X}$ = 11.201 SD = 2.867 N = 181	*L*: $\bar{X}$ = 11.319 SD = 2.734 N = 184	**L: $\bar{X}$ = 11.305 SD = 3.029 N = 197
	4	10.542	2.730	9							
LLH	1	11.572	2.759	11	LLH: $\bar{X}$ = 11.066 SD = 2.587 N = 42						
	2	12.265	2.346	11							
	3	9.812	2.826	9		LL*: $\bar{X}$ = 10.803 SD = 2.842 N = 88	L*L: $\bar{X}$ = 11.053 SD = 3.035 N = 93	*LL: $\bar{X}$ = 10.979 SD = 3.054 N = 96			
	4	10.385	2.035	11							
LLL	1	10.034	2.187	14	LLL: $\bar{X}$ = 10.563 SD = 3.064 N = 46						
	2	8.935	4.048	8							
	3	11.715	2.831	12							
	4	11.114	3.203	12							