A COMPARISON OF STRUCTURED AND UNSTRUCTURED MODES OF TEACHING ELEMENTARY SCIENCE PROCESS ACTIVITIES: THE INFLUENCE OF CREACTIVITY AND SEX OF STUDENTS

KEVIN RALPH BARTLETT

A COMPARISON OF STRUCTURED AND UNSTRUCTURED MODES OF TEACHING ELEMENTARY SCIENCE PROCESS ACTIVITIES: THE INFLUENCE OF CREATIVITY AND SEX OF STUDENTS

A THESIS
PRESENTED TO
THE FACULTY OF EDUCATION
DEPARTMENT OF CURRICULUM AND INSTRUCTION
MEMORIAL UNIVERSITY OF NEWFOUNDLAND

IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE
MASTER OF EDUCATION

---

by

© KEVIN RALPH BARTLETT

AUGUST, 1973

ACKNOWLEDGEMENTS

The writer wishes to acknowledge with gratitude the interest, encouragement, and competent guidance offered by Dr. R.K. Crocker, the supervisor of this study. Thanks are also extended to Dr. J. Smith and Dr. R. Reis for their valuable advice.

Appreciation is expressed to the administration and staff of the Central Elementary School in Twillingate and St. Joseph's Academy in Windsor where the experiment was conducted.

And finally, the writer wishes to express his deep appreciation to his fiancée who provided encouragement and invaluable companionship while the study was being conducted and the thesis being prepared.

ABSTRACT

Using process-oriented science activities adapted from Elementary Science Curriculum Study this study attempted to determine which instructional approach (structured or unstructured) students preferred and, at the same time, achieved at the highest level.

Intelligence scores and pretest scores were used as covariates in the analysis, while such independent variables as verbal creativity, figural creativity, and sex of the student were investigated for possible effects on achievement and preference.

A two week experiment was conducted in two Newfoundland elementary schools. These schools were in different areas and the sample consisted of 120 sixth grade students. Since each student was exposed to both the structured and unstructured treatment, it was necessary to have two sets of activities differing in content. One set dealt with balancing, while the other dealt with density-volume. Each set was then cast into a structured and unstructured approach. Because of the nature of the study (all students receiving both treatments) certain variables had to be counterbalanced in the experimental design. Included here were such variables as order of presentation and time of presentation.

A pretest and posttest were administered for each treatment to obtain information on achievement. Two weeks after the experiment ended a instrument designed to get student preference for treatment was administered. Data on the achievement was analyzed by means of linear regression, while the preference frequency tabulations were analyzed by means of chi-square.

The general conclusions from the study were that: (1) students

achieved significantly higher in the structured approach, and (2) students preferred the structured approach over the unstructured. However, in both achievement and preference, there was a significant class by treatment interaction. In addition, it was found that females achieved significantly higher than the males, however, neither verbal nor figural creativity interacted with the treatment, nor produced any main effect on achievement or preference.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

CHAPTER I

BACKGROUND OF THE STUDY

In the fall of 1970, a new science program, The Elementary Science Curriculum Study (ESCS), was introduced into a number of Newfoundland elementary schools. ESCS, which is organized around the process approach to the study of science, is now in its third edition and is used in approximately 400 classrooms in the province.

The idea of teaching science processes, as opposed to teaching the products of science, was not the organizational basis of a major science curriculum until 1965 when the AAAS released its curriculum, entitled Science - A Process Approach.

AAAS identified fourteen processes which were characteristic of scientific activity, and proposed that a deliberate and conscientious effort be made to teach these processes to elementary school students. Since the philosophy and rationale of ESCS is very similar to that of the AAAS, a modified version of the AAAS processes has been used as the basis of organization of the program.

Traditionally, the objective of most science courses was to instill in the student a prescribed quantity of facts so that he would be able to recall these facts. From new objectives and new goals, there emerged new curriculum projects such as ESCS. No longer were the processes an incidental part of science instruction; they were now brought to the fore, and content relegated to secondary importance.

Since the process approach emphasizes student involvement in the activities, it is related to the much broader concept of learning by discovery. Learning by discovery is usually defined as teaching an association, a concept or rule which involves the 'discovery' of that association, concept or rule (Glaser, 1966). In such an approach, the imposition of a structured instructional sequence is minimized in order to provide a relatively unguided sequence onto which the individual imposes his own structure.

Some alleged advantages of the discovery approach over expository approaches are 1. it requires more student involvement and hence has a motivational value, 2. the value of the task is increased due to the extra intellectual effort, and 3. it increases the child's expectancy that he is able to solve difficult problems autonomously (Kagan, 1966). In spite of widespread discussion of discovery learning, little substantiated knowledge exists about the advantages this approach offers, and under what conditions these advantages accrue. The state of knowledge in the field has been documented by Cronbach and others (1966).

The concept of discovery learning is a very broad one. Research problems in this area include conceptual issues, methodology, semantics, analysis and design. Approaching discovery learning experimentally is unwieldly unless the concept is delimited to a small part of discovery learning.

A process-oriented curriuclum such as AAAS or ESCS presents processes as content. In addition, when students are required to become familiar with these processes by means of a pedagogical technique emphasizing inquiry, the distinction between inquiry as content and inquiry as technique becomes particularly hazy.

STATEMENT OF THE PROBLEM

The problem was to study: 1. the effect of structured and unstructured teaching style on the attainment of science process skills and the possible interactions of style with creativity and sex when pretest scores and intelligence measures were taken as covariates, and 2. the relationship of preference for one instructional style to these same variables.

This investigation was part of a broader study involving another researcher. The broader study was still concerned with the effects of teaching style on achievement and preference of the students. However, in addition to the variables mentioned above, factors such as socio-economic status of students, and certain aspects of personality (extroversion, neuroticism, dependency) were investigated.

As stated previously, research on discovery learning has been plagued by many problems, only one of which is the confusion arising out of semantics. This study used an activity-oriented treatment and therefore might be classified under the general problem of discovery learning. However, the pedagogical technique used in the treatments placed a different degree of emphasis on independent student inquiry, even though the students were actively involved in both instructional styles.

DEFINITIONS

Process Approach

An approach to science teaching, the main objective of which is to teach the complex investigative behavior of scientists by decomposing it into simpler activities, which can be arranged in a hierarchy of complexity for purposes of instruction (Gagne, 1965).

Structured Approach

The student is presented with a problem, given an explicit behavioral objective and provided with detailed instructions about how to manipulate the apparatus to achieve the objective.

Unstructured Approach

The student is presented with a problem having an explicit behavioral objective, but is given no instructions as to how he should proceed so as to achieve the objective.

HYPOTHESES

A review of the related literature, and a consideration of the problems involved in implementing ESCS led to several questions that might be investigated. Based on this the following hypotheses were tested in this study:

A.1. There is no significant difference in student achievement between structured and unstructured process-oriented science activities.

A.2. There is no significant effect on achievement scores due to the interaction between structured and unstructured process-oriented science activities and 1. creativity 2. sex of the student.

B.1. There is no significant difference in student preference for structured and unstructured process-oriented science activities.

B.2. There is no significant effect on preference due to the interaction between structured and unstructured process-oriented science activities and 1. creativity; 2. sex of the student.

DELIMITATIONS OF THE STUDY

1. Time - The experiment was conducted for only two weeks.
2. Sample size - The experiment was restricted to four classes.
3. Treatment - The structured and unstructured approaches were used on just two topics, i.e. Balancing and Density.

LIMITATIONS OF THE STUDY

Any conclusions accruing from the study are limited by:

1. The lack of random sampling of participants and of assignment to experimental groups.
2. The reliability and validity of the instruments used in the study.
3. The size and nature of the sample.
4. The short duration of the experiment.

SIGNIFICANCE OF THE STUDY

Since modified activities of the Elementary Science Curriculum Study comprised the treatment, the information can be used as part of the formative evaluation of that project by suggesting the instructional technique or mode which appears to be effective under a particular condition.

Little literature exists to show the effects of instructional style on achievement in process-oriented curricula. Information these effects, combined with information gained on the students' preference for a particular style of instruction, should help form a composite picture of an environment where student interest and achievement are high.

The treatment in this study represents the two poles of an activity-oriented program. The researchers presented both approaches as being equally acceptable instructional techniques and no advantages were given one approach over the other. It was the belief of the investigators that a statement of one method being better than another is only meaningful in an individual context since the student's individual characteristics interact with the treatment to produce any change in behavior.

This study provided the same training time for both approaches, had the same objectives, and provided unbiased instruction in both approaches. In view of this, it is judged that the findings of this study will not be influenced by different objectives, or good instruction in one method and bad instruction in the other, and hence does not have many of the weaknesses found in much of the research on discovery learning.

CHAPTER 2

REVIEW OF THE LITERATURE

A search of the literature revealed that there was no consensus of opinion with respect to the use of "structured" or "unstructured" science activities in elementary school science. A variety of terms appear in the literature in relation to the "structured-unstructured" lab activity construct. For example, "self-directed" verus "teacher-directed", "abstract" verus "concrete", "deductive" verus "inductive", or "free" verus "guided" are just a few. However, in most cases, the authors were talking about the same thing, and they were defining their terms to meet their particular needs and the limitations of their study.

Lewis and Bolzano (1971) described "structured" to be the degree to which a teacher specifies the learning tasks in terms of scope and sequence - what the student is supposed to do is displayed in teacher-selected patterns; "unstructured" was defined as learning tasks which are unspecified and where students make their own options.

Tuckman (1967) defined an "abstract task" as one with multiple solutions and solution routes - in other words, no fixed or defined rules exist for solving the problem. He defined a "concrete task" as one which has a single clear solution and solution route, on the basis of objective and prespecified criteria defined by fixed rules.

Lansdown and Dietz (1965) defined "free-experimentation" as a situation where the student is faced with structured materials and told to see what he can find out. "Guided-experimentation" was defined as a situation where either by reading, discussion, or a pretest, the student orients his thinking toward specific problems for which he sets about to find solutions with structured materials.

Kline (1971) defined "teacher-directed" learning as a situation where each concept is introduced by the teacher, and possible solutions to the problems introduced are discussed. Students then go to the lab to implement the choice of solutions which they have chosen as the most appropriate. To Kline, "self-directed" learning involves no formal instruction from the instructor after the introduction on the first day.

The variety in the choice of terms is probably due to the variety of definitions of the approaches used in the studies, even though the methods were very similar in most cases. What the student did in Kline's "teacher-directed" learning is very similar to that in Tuckman's "concrete" tasks. The definitions used in the present study (see page 4) reflect many of the ideas expounded by the various researchers, but do not adhere to any of their definitions rigidly since the context of the learning tasks in this study is somewhat different from those reported in the research literature.

Numerous studies have been conducted in which achievement in a learning task was measured. Since the studies were seldom concerned with achievement in a set of learning tasks that emphasized the process aspect of science, it might be argued that the findings in the literature may not necessarily be applicable when a process orientation to a curriculum is used, and are, therefore, peripheral to the central issue of this research. The studies did , however, provide insights and aid in the formulation of hypotheses in the present study.

The following survey of the related literature is divided into three sections:

1. Studies of science process learning.
2. Studies dealing with achievement as influenced by the variables of interest.
3. Studies dealing with achievement as related to the degree of teacher structuring of learning tasks.

Studies Dealing with Science Process Learning

According to Gagné (1965), the process approach seeks the middle ground between a method based entirely on learning content and one where teachers deliberately undertake to 'train creativity'. The point of view is that if transferable intellectural processes are to be developed in the child for application to continued learning in the sciences, then intellectual skills must be separately identified, learned, and nurtured in a highly systematic manner. One of the key ideas of the process approach is the progressive building of more complex intellectual processes from simpler ones.

The most deliberate and most influential process-oriented elementary science curriculum course is Science - A Process Approach. It is completely process oriented, and it has served as a valuable guide to curriculum development, including such programs as the Elementary Science Curriculum Study.

Some of the premises of the ESCS are:

1. Science is for all students, and there should be an aim for a common literacy in science.
2. Science teaching at the elementary level must consider levels of development and thinking capabilities of students.

3. It is possible to draw a direct parallel between the increasing complexity of scientific processes and the levels of child development (Crocker, 1972). This implies that the teaching of science especially at the primary and elementary level can be in line with Piaget's stages of development. This would mean the child would learn concepts in a manner governed by his own stage of development.

Studies Dealing with Achievement as Influenced Creativity and Sex

Ray (1961), Vernon (1964), Edwards and Tyler (1965), Bentley (1969), Cicirelli (1965), Dacey and Madaus (1971), Callaway (1969), and Johnson (1969) have conducted experiments in which science achievement was measured as a function of such variables as intelligence, creativity, and sex, and how these variables interact to influence achievement.

In these studies, methods and materials differed. There was no consensus of opinion resulting from the research findings about how each variable interacted with the treatment and with the other variables, Some studies support the theoretical writing of Torrance (1962), and Getzels and Jackson (1962) which stated that creativity should influence achievement, while others tend to refute their ideas.

Ray (1961) carried out a study to find out if there were any differences in initial learning, retention and transfer between groups using two teaching methods (directed discovery and pupil discovery) and whether there was any interaction between the method and intellectual ability. Working on the assumption that directed discovery would be more effective with the brighter students, he found that this was not the case. There was no significant interaction between the teaching method and mental ability, that is, the directed discovery approach seemed equally as effective with pupils of low or of high ability. At the end of one week there was no significant difference in retention of material initially learned between students on either method; however, there was a significant difference in transfer in favor of the discovery approach. These findings are especially relevant to this study since the goal is to find out many of the same things but in relation to process learning.

Research on how intelligence affects achievement is much less frequent at the elementary school level than at other levels. Larin (1965) found the correlation between intelligence and grades in various subject areas to average about .65. Also, he reported a study where the correlation between intelligence and scores on a subtest of an achievement measure for students from grade one to four ranged from .31 to .63. Larin concluded that the research showed that the best predictions are obtained from multiple correlations in which a battery of intellective variables is used to predict overall grade-point average.

Clearly then, other factors must be involved, and should be used in the prediction of achievement scores. Vernon (1964) states that truly creative ability is relatively independent of whatever is measured by intelligence tests and/or school grades. Creativity is one of these factors and its effects on and relationship to intelligence, as measured by IQ, has received considerable attention. Anderson (1960) in his Ability Gradient Theory states that IQ could be expected to have an effect on academic achievement up to a threshold level, where further increases in IQ would have no further effect on achievement.

At this threshold, creativity would begin to have an effect. Mackinson (1961) supports the same view and suggests that the threshold might be around IQ = 120. Pielstick (1963), however, not only failed to find evidence for the theory, but found rather that the correlation between creativity and achievement decreased as IQ increased.

Getzels and Jackson (1962) and Torrance (1962) have hypothesized that intelligence and creativity show a very low correlation with one another and that creativity is as closely associated with achievement as is intelligence. However, Flescher (1963) found no evidence that creativity is as closely associated with achievement as is intelligence. He attributed his negative results to high correlations between intelligence and achievement, extremely low correlations between creativity indexes and IQ, and the questionable validity of the creativity tests. Torrance (1962) suggested that some of this variation might be due to the threshold effect.

Bentley (1966) proposed that creativity might influence achievement in a special way. He hypothesized that certain kinds of creative thinking abilities might contribute to certain kinds of achievement, thereby allowing the creative but less bright student to perform equally with his less creative but more intelligent fellow students. His findings tend to support the assumption that academic achievement consists of many abilities, only a few of which are measured by traditional tests of academic ability. The idea that creativity might affect certain kinds of achievement led to an investigation of the interaction of creativity and treatment in the present study.

Dacey and Madaus (1971), Callaway (1969) and Cicirelli (1965) also conducted research dealing with the interactive effects of creativity, intelligence and achievement. Dacey and Madaus hypothesized that at high IQ levels there will be a wide range of creativity, whereas as we go to progressively lower levels, the scatter for creativity will be less and less. They tested 867 eighth grade students from 23 junior high schools, using the Lorge-Thorndike Intelligence Test and four tests adopted from the Torrance's Test of Creative Thinking. Nearly all correlations were non-significant at low as well as at high IQ levels in all samples. Their results showed slight support for their hypothesis. They also attributed their low correlations to the questionable validity of the creativity tests.

Callaway (1969) hypothesized that scores on each of six personality dimensions associated with creative individuals would be positively correlated with verbal intelligence, and that groups high in verbal intelligence would be significantly higher at the .05 level than the low group on all personality dimensions. He derived his pertinent personality characteristics from examinations of the characters of Einstein and Coleridge, people in arts and sciences, and people in other diverse disciplines. He measured creativity by administering the Omnibus Personality Inventory. Intelligence was measured by the California Test of Mental Maturity. The population consisted of adolescents, which according to Dacey and Madaus (1971) may be a population for which creativity may be unreliable. His results showed a weak correlation in a positive direction between personality measures and IQ.

Cicirelli's (1965) main hypothesis was that there is an interactive effect between IQ and creativity, and beyond a certain level, increased IQ will not differentiate between individuals in terms of academic achievement. At this hypothetical level, creativity will begin to differentiate individuals in terms of achievement. Using 641 sixth graders, he divided them into 8 IQ categories and 3 creativity categories. IQ was measured by the California Short-Form of Mental Maturity, while the creativity scores were obtained from the Minnesota Test of Creative Thinking, Verbal and Nonverbal Form A. The results were not very convincing in that the interaction between IQ and creativity as it affects academic achievement was found in only one category. Three categories showed a linear increase in achievement with IQ up to 130-139 level, where an apparent plateau in achievement began. However, the other nine categories showed a linear relationship over the entire range of IQ sampled. Since the correlation of creativity and achievement was not significant at any IQ level, the interaction between IQ and creativity is probably best interpreted as chance findings. Since the hypothesis put forward by Cicirelli has not been substantiated, other factors such as how teaching method interacts with creativity and achievement might profitably be investigated.

Johnson (1969) attempted to tie most of the research together by conducting a study to determine 1. the relationship between IQ, creativity, sex, and achievement; 2. the relationship between the type of science program and achievement; and 3. the relationship between "high intelligent" and "high creative" groups and achievement variables. Using a sample of 736 students from a high school in Minnesota, and using the Torrance Test of Creative Thinking and the Lorge-Thorndike Intelligence Tests, he found that the creativity factors were not significantly correlated with achievement. He also found that high intelligent groups performed higher on achievement tests than did the high creative groups. His findings did not confirm the Getzels and Jackson idea that there is no difference. However, one serious limitation of Johnson's study was that the variable of classroom methodology was not taken into consideration.

Studies Dealing with Achievement as Related to the Degree of Structuring of Tasks

Three studies pertinent to the present research were found in the survey of the literature. These studies were not done with the same age level of students as used in this study, but they do provide valuable information on the general effects of structuring of learning tasks. Studies in this area were carried out by Rainey (1965), Kline (1971), and Tuckman (1967).

Rainey (1965) examined the effects of directed and non-directed laboratory work in high school chemistry. He used CBA as the non-directed approach and CHEM study materials as the directed approach. The study was designed to measure the effects on learning high school chemistry with lab exercises having specific and detailed instructions given in a directed way, verus the same exercises given in the form of problems without directions for their solutions. He found that the non-directed group were better able to recall the specifics about each lab experiment than the directed group; learning of principles and descriptive chemistry was not significantly different for the two approaches. One limitation of this study is that CBA and CHEM study differed in many variables other than the amount of teacher influence.

Triandis, Miksell, and Ewen (1962) did a study in which they found that groups homogenous in high creative ability outperformed groups heterogenous in creative ability on abstract, unstructured tasks. Based on this Tuckman (1967) carried out a study to document the hypothesis that group performance is influenced by the interaction of group composition and task demands, rather than by group composition alone. He divided the tasks into two types: 1. Abstract - multiple solutions and solution routes were appropriate, and there were no fixed defined rules for solving the problem; 2. Concrete - single, clear solutions and solution routes were correct on the basis of prespecified and objective criteria. He hypothesized that groups having individuals high in level of abstractness would perform more effectively on abstract tasks than groups in which there were individuals low in their level of abstractness, but that there would be no differences on the structured tasks. This hypothesis was confirmed. A serious limitation with respect to the generalizibility of the study is that the sample consisted of 36 Navy enlisted men having a mean age of 18, selected from the upper end of the intelligence distribution of the total available population. Also, the tasks were oriented more toward the military than academic matters.

Kline (1971) investigated the problem whether or not the Earth Science Curriculum Project open-ended lab block on soil could be learned as effectively by self-directed students as by teacher-directed students. He hypothesized that there would be no significant differences between the groups in cognitive understanding, achievement, difficulty in reading the material, or difficulty in the associated mathematics. He divided 97 junior high school students who were using ESCP into two control groups (teacher-directed) and two experimental groups (self-directed). All groups were under the same instructor and all participated in a pre and postlab discussion. Using an analysis of covariance on the postlab scores, which were adjusted with IQ as the covariate, he found that there were no significant differences on factors other than reading difficulty, providing the students had enough background information on the topic to enable them to make intelligent decisions. Even though difficulty with the reading level showed up for the self-directed group, it could not have been very serious because they achieved as well as the teacher-directed group on the postest. The finding that there were no significant differences in achievement in the two modes when IQ was taken as a covariate is of particular interest in the present study because here also, IQ was taken as a covariate. Since ESCP lab blocks place some emphasis on the process aspect of science, the present study should provide some additional information along the same lines.

A review of the literature revealed no information to show the effects of the sex of the student on performance in science process activities. Brown (1967), however, did find that males did achieve higher than females in science activities. Also, no information was obtained concerning student preference for a particular mode of instruction in science, nor how the variables under consideration in this study affect preference for certain types of learning tasks.

SUMMARY

As the survey of the literature revealed, achievement, like most factors in the behavioral sciences, is a function of many variables. As the studies by Johnson and Cicirelli show, there is a need to examine closely the effect of teaching and classroom methodology upon achievement, and how the variables of intelligence and creativity interact with the methodology to affect achievement.

CHAPTER 3

POPULATION AND SAMPLE

The treatments in the study involved an adaptation of activities found in the Elementary Science Curriculum Study (ESCS), and therefore, could not be given to any students who might have already participated in any of the activities found in the treatments. The investigators, then, needed to find a sample of sixth graders who had not been exposed to a process approach to science instruction. The population in the study may be regarded as a hypothetical one consisting of all sixth grade classes similar to the ones used. The sample consisted of four classes having a total of 120 students. Two of these were in Twillingate, Newfoundland, the others, in Windsor, Newfoundland.

With this sample, we assumed that both the rural and the more urban elements of the population were represented. Because of the intact classes, the groups did not have pre-experimental sampling equivalence. The groups may have had some similarities, but not enough to permit elimination of the pretest. The random assignment of individuals to particular treatment groups was not feasible due to the administrative inconvenience it would cause in the schools involved in the study.

TREATMENT

It should be noted that this study was part of a broader study which attempted to investigate student achievement in and preference for structured and unstructured science activities. Other variables that were considered were certain personality types and socio-economic status of the students.

Once the experimental procedure had been formulated, the first task of the investigators was to select, adapt, and organize the science process activities that would constitute the treatment. The ESCS program is designed in such a way that each activity has its own objective, written in behavioral terms. Maintaining the given objectives, two sets of five activities each were modified so as to be consistent with the definitions of structured and unstructured teaching style as defined in Chapter 1. The activities were selected so as to form a unified sequence on a particular topic. Density-volume and balancing activities were chosen because the activities in ESCS on these topics followed an orderly sequence and could be covered during the experiment.

In the structured approach, students were given detailed instructions on how to approach the problem and how to manipulate the apparatus. Questions were posed by the instructor as the activity progressed so as to focus the student's attention on certain crucial aspects of the activity. Teacher involvement was controlled, but not to the extent that the classroom situation became overly inflexible. Following the activity, discussion was centered around specific questions; when the student's questions diverged from those specified, the instructor reoriented the discussion.

In the unstructured approach, the students were presented with the purpose of the activity and the necessary apparatus. However, the students were not given the method or means of achieving the purpose, nor were they given any instructions on how to manipulate the apparatus.

Post-activity discussion was completely determined by the student's questions, and any digressions were accepted as part of the activity. In both treatments, the students actually conducted the investigations.

PILOT STUDY

A pilot study was carried out over a two-week period at Dawson Elementary School in St. John's, Newfoundland. The pilot study was designed to achieve two purposes: 1. to provide an opportunity for the investigators to work through the activities in both modes of instruction so any inherent difficulties could be discovered; 2. to provide an opportunity to carry out reliability studies on the achievement and preference instruments.

During the pilot study, one investigator took one class of sixth graders and allowed the students to carry out the acitivities on density-volume in a structured approach, while the other investigator, using another class of sixth graders, carried out the activities on balancing in an unstructured approach.

At the end of the pilot study, test-retest reliability studies were carried out on the achievement and preference instruments.

EXPERIMENTAL DESIGN

Due to the inconvenience that would have been imposed on the school, classes had to be kept intact. In some cases, therefore, due to the policy of the school, students were homogenously grouped, while in others, heterogenous grouping was found. Therefore, random assignment of students to treatment groups was not carried out. This necessitated that the study be cast in more of a quasi-experimental design similar to the Nonequivalent Control Group Design of Cambell and Stanley (1963).

To overcome some of the effects of non-randomized selection and assignment, certain variables had to be counterbalanced. It was hoped that this would reduce the number of extraneous variables that might affect, or interact to affect, the results of the experiment. The variables that were counterbalanced were order of presentation of the activities, order of instructional mode for each class, as shown in Table I, and the instructors, both teaching both modes.

Counterbalancing the effects of these variables helped offset such effects as achievement and preference being a function of which treatment they were exposed to first, or knowledge that might have been gained from exposure to a preceding set of activities. As a result, the differences that do appear can now be more strongly argued to be a function of the independent variables under consideration.

In order to counterbalance the various extraneous effects, the experiment was conducted as shown in Table 1. Classes 2 and 3 were in Twillingate; classes 1 and 4 in Windsor. The experiment was designed so that in the second week a student received a set of activities in a different instructional mode and in a different content area from what he received during the first week.

At the beginning of each treatment period, a pretest was administered. Following the treatment, the same test was administered a second time. This procedure was designed to measure changes in achievement due to the effects of the treatment.

TABLE I

OUTLINE OF EXPERIMENTAL DESIGN

Class	Week 1	Week 2
1	SB	UD
2	UD	SB
3	UB	SD
4	SD	UB

Key

S - structured appraoch

U - unstructured approach

B - balancing activities

D - density-volume activities

INSTRUMENTATION

Science Process Achievement Tests

Since the treatment consisted of a series of activities adapted from ESCS, which to date has no process instruments accompanying it, a major part of the preliminary work involved constructing instruments to measure achievement in process skills. The AAAS Science Process Instrument (Experimental edition) and the process instruments constructed by Tannenbaum (1971) and Goulding (1972) were examined, but due to the rather specific nature of the treatment, only a few sample items could be adapted to suit the purposes of the study. However, some insights were obtained about the nature of the kind of information tested and how an item could be constructed so as to demonstrate if a student has internalized the process under consideration.

To evaluate the effects of treatment on achievement, two process achievement instruments were constructed - one dealing with balancing, the other with density-volume. The items included were constructed independently of any mode of instruction. Rather, each was constructed on the basis of one of the behavioral objectives. For this reason, the investigators judged that the instruments were not biased toward either of the teaching styles. Therefore, if the results indicated greater achievement in one mode, these differences will be attributed to effects other than test biases.

One common method of validating instruments is to correlate them with other instruments designed to measure the same thing. In the absence of comparable instruments, other procedures can be used. In this study, validation was done by submitting the instrument to the scrutiny of people who might be considered experts in the area of process learning.

The panel of experts consisted of three science educators at Memorial University and three sixth grade teachers who are currently teaching a process-oriented science course to their classes. It was felt that the addition of active teachers to the list of validators would provide valuable information on the level of difficulty of items that typical sixth graders are capable of handling.

Each of the validators was given a set of activities and both the process achievement instruments. For an item to be considered suitable, two-thirds of the validators had to give their approval on each of the following categories: clarity, appropriateness in light of process tested, and level of difficulty of the items (see Appendix A). The validating procedure was an adaptation of the one used by Tannenbaum (1971).

Reliability studies on the achievement instruments were conducted using a test-retest procedure in the pilot study. One class completed the Achievement Test I on balancing, the other Achievement Test II on density-volume. After a period of two weeks, the tests were administered to the respective classes for the second time. The Pearson Product Moment Correlation Coefficient was calculated and the correlation between scores on the test-retest for Achievement Test I was .76, and for Achievement Test II, it was .72.

Preference Scale

In addition to the achievement measures, the study dealt with which instructional mode by the Pearson product moment correlation coefficient

TABLE II

MEAN, STANDARD DEVIATION AND RELIABILITY OF THE PROCESS ACHIEVEMENT TESTS

	FIRST ADMINISTRATION		SECOND ADMINISTRATION		
	MEAN	STANDARD DEVIATION	MEAN	STANDARD DEVIATION	CORRELATION COEFFICIENT PEARSON-PRODUCT MOMENT
Achievement Test I (Balancing)	8.0	2.5	7.7	2.9	0.76
Achievement Test II (Density)	9.2	2.8	8.3	2.4	0.7

preference, a semantic differential was constructed on which students would indicate their attitude toward "learning with many instructions" verus "learning with few instructions". The investigators reasoned that a difference between the scores for these two concepts would provide a measure of the student's preference for one of the modes of instruction.

Test-retest reliability studies were conducted over a two week period as part of the pilot study. It was found that all students responded highly positively on both concepts. The result could probably be attributed to the novelty of this type of science activity. Because of the restricted range of scores, the test-retest reliability was low when calculated by the Pearson product moment correlation coefficient.

The semantic differential, therefore, did not appear refined enough to provide the information sought. Another instrument, sampling the same attitudes as in the semantic differential but forcing the students to make a choice between the two modes of instruction, was therefore, constructed. The ideas contained in the scales of the semantic differential were cast into simple, concise questions and the students were required to respond by choosing the instructional mode most suited to the particular question. This forced choice procedure yielded a more direct measure of preference then did the semantic differential.

Because the instrument was constructed post facto, test-retest reliability studies could not be carried out.

Torrance Test of Creative Thinking

The creativity scores used were obtained from two forms of Torrance's tests, Thinking Creatively with Pictures, Form B and Thinking Creatively with Words, Form B. The reliability coefficients reported for these tests vary from study to study because different researchers considered different activities rather than the entire battery. With a battery consisting of most of the tasks in the verbal and figural forms A and B, Goralski (1964) obtained test-retest coefficients of .82, .78, .59, and .83 for fluency, flexibility, originality, and the total battery.

Even though an air of controversy surrounds the validity of these creativity tests, the investigator accepted the findings of Torrance as reasonable evidence of the validity of these instruments. It would be impossible to provide all research workers and potential users of tests of creative thinking satisfactory evidence of validity (Torrance, 1966).

Torrance has found that T-scores based on fifth grade data are rather satisfactory at all educational levels, so raw scores in this study were converted accordingly.

The investigator was concerned with finding some over-all measure of verbal and figural creativity for each student. In general, finding a composite is not recommended since the composite tends to reduce the range of scores for each of the components, therefore a high score on one component, such as originality, and a low score on another, such as fluency, will show up as an average score. However, such a score does seem to give a rather stable index of the total amount of creative energy a person has available or is willing to use (Torrance, 1966).

The Lorge-Thorndike Intelligence Test

To obtain measures of intelligence, Level D, Form 1 of the Lorge-Thorndike Intelligence Test was administered.

The reliability coefficient for both the verbal and nonverbal part of this test is reported as .91, and the correlation between the verbal and nonverbal part is reported as .61. From these figures, it can be seen that there is enough in common between the two measures to make it reasonable, for most students, to average IQ's from the two batteries to yield a single more comprehensive and more reliable measure of overall intellectual ability (Lorge, Thorndike, Hagen, 1967).

According to Freeman (1959), the Lorge-Thorndike series is one of the more sound group instruments available from the point of view of psychological insights shown in selecting and developing materials, and from the point of view of statistical analysis of the standardization data.

On the basis of three validating criteria, the Lorge-Thorndike series fares well. It is designed to elicit 'intelligent' responses by using items dealing with symbolic relationships. Also, it correlates highly with other instruments designed to measure the same thing. However, there is no predictive validity data available (Lorge, Thorndike, Hagen, 1967).

STATISTICAL DESIGN

All achievement scores were analyzed by means of Multiple regression analysis. Multiple linear regression has been recognized as having great potential for investigating the relationships between a set of independent variables (predictors) and a dependent variable (criterion)(Ward, 1962). The basic assumption of multiple linear regression is that there exists a linear relationship between the set of predictors and the criterion. Information about these predictors then gives the investigator certain predictive ability about the criterion.

The observed product-moment correlation (R) between Y (the observed criterion score) and Y (the predicted criterion scores) is a measure of the goodness of fit between the observed and predicted values of the criterion. Its square, the squared multiple correlation (RSQ) represents the amount of variance of the criterion accounted for by the full linear equation, usually called Model 1. To investigate the effect of a particular variable, a second equation, usually called Model 2, is used omitting that particular variable. It is possible to test the significance of the contribution of any one variable in the presence of the others by computing an F ratio, which incorporates the difference between the RSQ of the full model and that of the restricted model. Since the regression analysis will tell only if there is a significant difference, the researcher must re-examine the means of the cells in the design to determine the direction of that difference.

All the information on preference for treatment was analyzed by means of the chi-square statistic. The data on preference consisted of frequency tabulations, rather than actual scores and the chi-square provides a measure of the goodness of fit of this observed data to the expected data. The value of the chi-square can then be used to determine the probability of obtaining differences as great as those observed due to sampling error alone.

In the present study, data on preference consisted on frequency tabulations of the number of people who preferred one treatment over the other. The chi-square was used to determine if differences were great enough to be attributed to factors other than chance.

Because the same group of students was exposed to both sets of activities, two separate achievement instruments had to be constructed. In the analysis, both instruments were treated as one, in other words, the scores were standardized over the two instruments. Another procedure that could have been used was to standardize over each individual instrument. Using the second technique would eliminate the problem of differences between the instruments. Upon analysis of the data standardized over all scores, it was found that there was no significant difference between the two instruments. The researchers, in view of this, judged that this standardization procedure was satisfactory. If the standardization had been done over the two instruments instead of one, then an interaction between the class and the type of activity may have shown up, thus clarifying a little more the class-treatment interaction.

CHAPTER IV

RESULTS OF THE ANALYSIS OF THE DATA

The results of the analysis of the data are presented in the same order as the hypotheses in Chapter I. The hypotheses can be divided into two categories: 1. main effects and interactions of certain variables on achievement, and 2. main effects and interactions of certain variables on preference for treatment. Since, in all cases, subjects were exposed to the two experimental treatments, emphasis was placed on how the independent variables may have interacted with the treatment to affect both achievement in and preference for a particular treatment.

It has become an accepted pedagogical fact that intelligence plays an important role in achievement. For this reason, the investigators considered using IQ scores as a covariate in the analysis. This decision can be justified by examining Table III which shows that the class mean IQs vary substantially from each other. By using IQ as a covariate, and thus using the residual scores, the effects of that variable were eliminated. In addition, from superficial examination it became apparent that pretest scores were also fairly high. To eliminate these effects, pretest scores were also used as a covariate in the analysis.

Table IV shows the intercorrelations that existed between the variables considered in the regression equations. Verbal and figural creativity correlated very low with IQ scores and pretest scores, suggesting that the creativity tests and the intelligence tests appear to be evaluating different things, and that creativity did not affect achievement. There was, however, a significant correlation between IQ

TABLE III

AVERAGE IQ FOR EACH

CLASS IN SAMPLE

Class 1	91
Class 2	107
Class 3	91
Class 4	87

TABLE IV

INTERCORRELATIONS BETWEEN THE VARIABLES

	IQ	V. CREAT	F. CREAT	PRETEST	POSTTEST
IQ	1.0	.17	.15	.32	.41
V. CREAT		1.0	.28	-.11	-.02
F. CREAT			1.0	-.13	-.00
PRETEST				1.0	.45
POSTTEST					1.0

scores and posttest scores.

The first section of Table V gives the mean achievement score and the standard deviation of each class on the two treatments. In addition, both the overall class mean is given as well as the overall mean for the two treatments. The remainder of Table V and all of the other tables providing information on the cell means in the various experimental designs follow the same format.

Table VI presents the Squared Multiple Correlation (R^2) for the full model and the restricted model using different predictors. The difference between the R^2 for the two models gives the relative efficiency of that predictor. The table also provides the F-ratio, and the probability of obtaining that value of F. A probability of less than 0.05 was considered significant.

TABLE V

MEANS AND STANDARD DEVIATIONS OF ACHIEVEMENT SCORES FOR CLASS, TYPE OF ACTIVITY, TIME AND INTELLIGENCE

		STRUCTURED		UNSTRUCTURED		$\bar{X}$.
		MEAN	STAN. DEV.	MEAN	STAN. DEV.	
Class	1.	8.65	1.93	7.54	2.39	8.11
	2.	8.64	2.31	9.88	2.22	9.29
	3.	7.40	2.17	6.85	2.21	7.12
	4.	8.91	2.41	6.76	2.32	7.79
		8.38		7.76		
Type of Activity						
Balancing		8.68	2.13	6.80	2.26	7.74
Density-Volume		8.13	2.41	8.78	2.57	8.45
Time						
Week 1		8.78	2.18	8.33	2.68	8.56
Week 2		8.00	2.34	7.13	2.39	7.57
Intelligence						
High		9.80	2.12	9.31	2.63	9.56
Medium		8.08	2.67	7.63	2.15	7.86
Low		7.55	2.03	6.38	2.34	6.97

TABLE VI

EFFECT OF CLASS, TREATMENT, TYPE OF ACTIVITY, TIME AND INTELLIGENCE ON ACHIEVEMENT

Predictors	Covariates	df	R^2(Full)	R^2(Res)	F	Prob.	Significance
Class x Treatment	IQ Pretest	3/181	.36	.32	3.54	0.02	S
Main Effect of Class	IQ Pretest	3/184	.32	.30	2.23	0.09	N.S.
Treatment Main Effect	IQ Pretest	1/184	.32	.31	4.48	0.04	S
Type of Activity x Treatment	IQ Pretest	1/184	.31	.31	0.79	0.38	N.S.
Main Effect of Activity	IQ Pretest	1/185	.30	.30	0.80	0.37	N.S.
Time x Treatment	IQ Pretest	1/184	.34	.33	1.44	0.23	N.S.
Main Effect of Time	IQ Pretest	1/185	.33	.30	8.46	0.00	S
Intelligence x Treatment	Pretest	2/184	.30	.30	0.32	0.73	N.S.
Main Effects of IQ	Pretest	2/185	.30	.22	10.40	0.000	S

EFFECT OF TREATMENT ON ACHIEVEMENT

Hypothesis A.1. There is no significant difference in student achievement between the structured and the unstructured process-oriented science activites.

The value of the F-ratio (4.48) and the probability of getting this value (0.035)(See Table VI) suggests that there was a significant difference between the treatments so the null hypothesis was rejected. This result, however, needs to be interpreted in light of the class-treatment interaction which will be discussed later.

Hypothesis A.2.1. There is no significant effect on achievement due to the interaction between structured and unstructured process-oriented science activities and creativity.

The low value of the F-ratio for verbal creativity (0.357) as seen from Table VIII, and the high probability of getting that value suggests that there was no interaction between verbal creativity and treatment. Similarly with figural creativity and treatment where the value of the F-ratio was 0.219 and the probability 0.803. Therefore, the null hypothesis failed to be rejected.

Hypothesis A.2.2. There is no significant effect on achievement due to the interaction between structured and unstructured activities and the sex of the student.

This hypothsis was not rejected on the grounds that the F-ratio (0.374) was low and the probability (0.541) of getting that value was high (See Table X). However, further analysis revealed that a significantly higher level was achieved by the females.

TABLE VII

MEANS AND STANDARD DEVIATIONS OF VERBAL AND FIGURAL CREATIVITY

	STRUCTURED		UNSTRUCTURED		$\bar{X}$.
	MEAN	STAN. DEV.	MEAN	STAN. DEV.	
VERBAL CREATIVITY					
HIGH	8.62	2.09	7.38	2.17	8.00
MEDIUM	8.23	1.89	8.13	2.25	8.18
LOW	8.23	2.95	7.41	3.41	7.82
FIGURAL CREATIVITY					
HIGH	8.05	2.31	7.74	2.98	7.89
MEDIUM	9.26	2.16	7.81	2.45	8.53
LOW	7.75	2.11	7.75	2.19	7.75

TABLE VIII

EFFECT OF VERBAL AND FIGURAL CREATIVITY ON ACHIEVEMENT

Predictors	Covariates	df	R^2(Full)	R^2(Res)	F	Prob.	Significance
Verbal Creativity x Treatment	IQ Pretest	2/177	.31	.31	0.36	0.70	N.S.
Main Effects	IQ Pretest	2/178	.31	.31	0.36	0.70	N.S.
Fugural Creativity x Treatment	IQ Pretest	2/180	.32	.32	0.22	0.80	N.S.
Main Effects	IQ Pretest	2/181	.32	.32	0.76	0.47	N.S.

Discussion

Because of the lack of random assignment, and in spite of the counterbalancing procedures used, the possibility existed that the variables of class, type of activity, and order of presentation could interact with treatment. As a preliminary to testing hypothesis A.1 for the main effects of treatment, an analysis was conducted to determine if there was a significant interaction between class and treatment. This procedure was warranted by the fact that the means for class 2 (See Table V) were reversed relative to the other classes with respect to achievement on a particular treatment. The F-ratio (3.54) and the probability (0.016) suggested that the interaction was a significant one.

In view of the findings on class-treatment interaction, any consideration of main effects of treatment must be considered cautiously. However, due to the nature of the interaction, the means for the treatments were closer than they would be if this interaction did not exist. It is especially interesting, therefore, that in spite of this interaction there was a significant difference in the main effects of the treatment in favor of the structured approach.

Further analysis was carried out to endeavour to determine the possible causes of this class-treatment interaction. Such factors as intelligence, type of activity, time of presentation, plus the original independent variables (creativity and sex) were examined. As Tables VI, VIII, and X suggest, none of these variables interacted significantly with the treatment. This leads one to suspect that two or more of these variables may work together to cause this interaction. Unfortunately, these higher-order interactions cannot be investigated by the method of analysis used in this study. As part of the broader study (See Chapter I),

TABLE IX

MEANS AND STANDARD DEVIATIONS FOR EACH SEX

	STRUCTURED		UNSTRUCTURED		$\bar{X}.$
	MEAN	STAN. DEV.	MEAN	STAN. DEV.	
Sex					
Male	7.73	2.12	7.67	1.94	7.70
Female	8.94	2.40	8.19	2.92	8.56

TABLE X

EFFECT OF SEX OF STUDENT ON ACHIEVEMENT

Predictors	Covariates	df	R^2(Full)	R^2(Res)	F	Prob.	Significance
Sex x Treatment	IQ Pretest	1/179	.36	.35	0.37	0.54	S.N.
Main Effect	IQ Pretest	1/182	.36	.32	11.18	0.00	S

it was found that the personality factor, neuroticism, did interact with treatment such that the more neurotic students achieved better in the structured approach. Also, high socio-economic student achieved significantly higher than students from other SES levels. However, there was no evidence that class 2 was biased with a large number of high SES, neurotic students.

The means from week 1 were also significantly higher than week 2. In addition, it was found that high IQ students achieved significantly better than students with lower IQ. Since IQ was used as a covariate in the analysis, this did not appear to be a justifiable explanation of the interaction. However, since class 2 received unstructured treatment in week 1 and that class had the highest mean IQ, it is possible that these two factors may together have influenced the results.

Therefore, within the scope of the variables under consideration, no clear cause of the class-interaction was found. It can only be suggested that it was due to some higher-order interactions which could not be investigated.

In this study, neither verbal creativity nor figural creativity interacted with treatment to affect achievement. A possible explanation of this finding is that the treatment did not provide ample opportunity for creative students to excel. Any null results, however, need to be interpreted cautiously because the results may be due to errors in measuring the variables.

Generally the null results in the study may possibly be attributed to novelty of the type of science activities causing almost equal effects regardless of instructional technique used. Also, depending on the amount of teacher structure the students were accustomed to, both styles may have been relatively unstructured.

EFFECT OF TREATMENT ON PREFERENCE

The frequencies for the preference were obtained by administering the instrument described in Chapter III. The scores could range from 0 to 10. If the score was between 0 to 3 (inclusive) it signified preference for one method, 4 to 6 represented a neutral feeling, and 7 to 10 represented a preference for the other treatment. The number of students falling into each category was then tabulated.

When dealing with chi-square, the idea of independence is equivalent to lack of interaction in the regression analysis. If when using chi-square, there is a significant difference, this is equivalent to saying that factors other than chance are operating to influence the result and the variables are not indpendent. This is synomyous with saying the variables interact to affect the criterion when using regression analysis.

The tables on student preference contain both expected, (in parentheses in the table) and observed frequency tabulations, the value of chi-square, and the probability of getting that value of chi-square.

Hypothesis B.1. There is no significant difference in student preference for structured and unstructured process-oriented science activities. Table XI shows the number of students preferring each mode of instruction.

The calculated chi-square for the observed frequencies in Table XI was 12.43. The probability of getting this value was less than 0.05. The null hypothesis was therefore, rejected.

Hypothesis B.2.1. There is no significant effect on preference due

TABLE XI

EFFECT OF TREATMENT ON PREFERENCE

Structured	Neutral	Unstructured	Total
52(36)	23(27)	24(36)	99

χ^2 = 12.43 (df = 2), prob. < .05, S

TABLE XII

EFFECT OF TIME ON PREFERENCE FOR TREATMENT

Time	Structured	Unstructured	Total
Week 1	28(28)	14(13)	42
Week 2	23(22)	10(10)	33
	51	24	75

χ^2 = 0.11 (df = 1), prob. > .05, N.S.

TABLE XIII

EFFECT OF TYPE OF ACTIVITY ON PREFERENCE

Activity	Structured	Unstructured	Total
Balancing	22(18)	6(9)	28
Density	27(30)	18(15)	45
	49	24	73

χ^2 = 2.83 (df = 1), prob. > .05, N.S.

to the interaction between structured and unstructured process-oriented science activities and creativity.

The chi-square value for figural creativity (See Table XVI) was such that the probability of obtaining that value was greater than 0.05 in both cases, so the hypothesis was not rejected.

Hypothesis B.2.2. There is no significant effect on preference due to the interaction between structured and unstructured process-oriented science activities and sex of the student.

The chi-square (0.52) associated with the observed frequencies had a probability of greater than 0.05 of occuring. The null hypothesis was accepted.

Discussion

Again, as part of the analysis of hypothesis B.1, regarding the treatment most preferred by the students, a detailed consideration was also given to possible interaction between treatment and other variables. These findings are reported in Tables XII to XVIII.

Even though more subjects preferred Density-volume activities and the structured treatment, there was no significant interaction between the type of activity and the mode of instruction.

However, just as there was a significant interaction between class and treatment with respect to achievement, so also was there one with respect to preference. In both cases, class 2 appeared to contribute most to the interaction. This interaction may be partially explained by the interaction which existed between intelligence and treatment (See Table XV). It can be seen that in the high intelligent group more people preferred the unstructured treatment, while only one

TABLE XIV

EFFECT OF CLASS ON PREFERENCE FOR TREATMENT

Class	Structured	Neutral	Unstructured	Total
1	18(15)	6(6)	4(7)	28
2	6(12)	4(6)	14(6)	24
3	18(11)	3(5)	0(5)	21
4	10(14)	10(6)	6(6)	26
	52	23	24	99

$\chi^2 = 25.2$ (df = 6), prob. $< .05$, S

TABLE XV

EFFECT OF INTELLIGENCE ON PREFERENCE FOR TREATMENT

Intelligence	Structured	Neutral	Unstructured	Total
High	15(14)	1(6)	12(6)	28
Medium	17(19)	11(8)	9(8)	37
Low	17(14)	9(6)	1(6)	27
	49	21	22	92

$\chi^2 = 17.94$ (df = 4), prob. $< .05$, S

TABLE XVI

EFFECT OF FIGURAL CREATIVITY ON PREFERENCE FOR TREATMENT

Fig. Creat.	Structured	Neutral	Unstructured	Total
High	26(26)	13(12)	13(12)	52
Medium	16(14)	8(7)	5(7)	29
Low	9(9)	3(4)	6(4)	18
	51	24	24	99

$\chi^2 = 2.45$ (df = 4), prob. $> .05$, N.S.

TABLE XVII

EFFECT OF VERBAL CREATIVITY ON PREFERENCE FOR TREATMENT

Ver. Creat.	Structured	Neutral	Unstructured	Total
High	15(16)	9(8)	9(8)	33
Medium	19(20)	10(10)	13(10)	42
Low	14(11)	6(5)	3(5)	23
	48	25	25	98

$\chi^2 = 3.06$ (df = 4), prob. $> .05$, N.S.

TABLE XVIII

EFFECT OF SEX ON PREFERENCE FOR TREATMENT

Sex	Structured	Neutral	Unstructured	Total
Males	28(28)	14(13)	12(14)	54
Females	23(23)	10(11)	13(12)	46
	51	24	25	100

$\chi^2 = 0.52$ (df = 2), prob. > .05, N.S.

student in the low intelligent group preferred the unstructured treatment. Since, according to Table II, class 2 had the highest mean IQ, a treatment x IQ interaction can, in this case, manifest itself as a treatment x class interaction. Also, class 2 may have some undetermined attributes which caused it to differ.

Even though none of these variables can be definitely stated as the cause of the interaction when considered separately, the possibility exists that they may collectively influence the results.

SUMMARY

Multiple linear regression was used to determine if achievement scores were significantly better in one mode of instruction than in the other. Since achievement can be affected by so many variables, major emphasis in the analysis was given to how certain variables interact with the treatment so as to affect achievement scores.

An interaction was found between class and treatment. This interaction could not be fully accounted for by the analysis proceduce used, possibly because of the undetectable higher order interactions that may have existed between the variables. However, in spite of the effect that the interaction had on the means of the treatments there was a significantly higher mean for the structured treatment.

Preference was analyzed by means of the chi-square statistic. This provided evidence of the probability that the observed frequencies were significantly different from those expected. The structured treatment was preferred, but this must be interpreted in light of the fact that there was an interaction between class and treatment and between IQ and treatment such that there was a tendency for those having high IQ to prefer the unstructured approach.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

Process-oriented science curricula have been popular since the mid-sixties, but little research exists as to the best instructional technique to be used in the classroom with such courses. This study attempted to determine if student achievement and preference were influenced by particular types of instruction, namely structured and unstructured (as defined in Chapter I).

Four classes totalling 120 students comprised the sample. Each class was exposed to a structured and an unstructured treatment over a two week period. Since each student received both treatments, two sets of activities had to be constructed - one on balancing, the other on density-volume. Counterbalancing procedures were used in order to reduce the effects of such variables as type of activity and the order of presentation.

A pretest and a postest were administered for each treatment to obtain a measure of change in achievement. The information on the independent variables was obtained prior to the experiment by administering appropriate standardized tests. The data was analyzed by means of multiple linear regression.

Student preference for the treatments was measured two weeks after the experiment ended. Their opinions were given on a questionaire on which they responded either in favor of one of the treatments or a neutral response. The chi-square statistic was used to analyze the data.

CONCLUSIONS

The conclusions and discussions are based on the data analysis found in Chapter IV.

1. The findings indicated that students achieved significantly better in a structured approach than in an unstructured approach in process-oriented science activities.

This has to be interpreted in light of the class-treatment interaction which caused the means for the two treatments to be closer to each other. It appeared that class 2 was atypical with respect to the rest of the sample. If the analysis had treated class 2 separately because of its atypical nature, it appears that there would have been a more significant difference between the two treatments.

2. Irrespective of treatment, achievement scores were significantly higher for week 1 over week 2.

Contrary to popular belief, prior exposure both to type of material and methodology did not positively influence the results of the second week.

3. Females achieved significantly higher than males.

This finding also seemed to contradict the views put forward by Brown (1967) which stated that science was considered a 'male' subject and therefore males should achieve at a higher level.

4. Neither verbal nor figural creativity interacted with the treatment, nor produced any main effect on achievement.

The table of correlations indicated a low correlation between creativity scores and IQ scores, suggesting that different types of ability were being measured by the IQ and creativity tests. Also, a low correlation between creativity measures and achievement suggested that these activites may not be constructed so as creative people might excel.

There is, however, a limitation with respect to the creativity scores which may have influenced the above results. Even though the scores were categorized as high, medium and low, this division was based on the sample scores rather than the norms. With respect to the norms, few students had a T-score above 60. Therefore, it might be argued that few truly creative students, as measured by the instruments, were involved.

5. More students preferred the structured treatment over the unstructured treatment.

This finding has several implications for the broader concept of discovery learning. It would appear from this study that students prefer to have guidance instead of working by themselves. Also, students achieved significantly better in the structured approach. If structured process learning is better (both in terms of achievement and preference) then the parallel between process learning and discovery may not be meaningful.

6. There was a significant interaction between class and treatment and between IQ and treatment to affect preference for a treatment.

More high IQ students preferred the unstructured treatment than did the low IQ students. Also, the class-treatment interaction may have been caused by the class having the highest mean IQ. It would appear that these two are related so as to be partially responsible for the interaction.

7. Neither sex of the student nor creativity measures affected preference for either treatment.

RECOMMENDATIONS

The following recommendations arise from either the data analysis or suggestions as to how to improve control over certain variables. The investigators feel that the basic design of this study is a sound one, and any recommendations are only valid as long as that premise is accepted.

1. It is suggested more accurate and reliable findings could be obtained if the study were conducted over a semester, rather than a two week period. This would result in a more extensive program, and thus would provide a clearer picture of the actual student achievement (and preference). In addition, the extension of the treatment would allow the use of a much longer and more reliable instrument.

2. Further research should be attempted to determine if the finding of this study with respect to achievement in unstructured activities by high IQ students is an accurate one. A study designed for that purpose should be conceived and carried out.

3. Even though the findings suggest that creativity is not important in such a program, more detailed investigations need to be conducted before any definitive conclusion is reached.

BIBLIOGRAPHY

AAAS Commission on Science Education. The Psychological Basis of Science - A Process Approach. AAAS Miscellaneous Publication, 1965.

Anderson, J.E. "The Nature of Abilities". In E.P. Torrance (ed) Talent and Education, Minneapolis University, Minnesota Press, 1960.

Bentley, J.C. "Creativity and Academic Achievement", Journal of Educational Research, 59: (1966), 269-72.

Brown, C.K. "Pupil Personality, Teaching Style and Achievement", Unpublished Doctoral Thesis, University of Alberta, 1967.

Callaway, W.R. "A Holistic Conception of Creativity and its Relationship to Intelligence", Gifted Children Quarterly, 13 (Winter 1969), 237-41.

Cambell, D.T. and Stanley, J.C. Experimental and Quasi-Experimental Designs for Research. Rand McNally and Co., Chicago, 1963.

Cicirelli, V.G. "Form of the Relationship Between Creativity, IQ, and Academic Achievement", Journal of Educational Psychology, 56(6) 1965, 303-8.

Crocker, R.K. Elementary Science Curriculum Study, Grades 4-6: A Teaching Guide (Third Trial Edition). Newfoundland Department of Curriculum and Instruction, Memorial University of Newfoundland, 1972.

Dacey, J.S. and Madaus, G.F. "A Analysis of Two Hypotheses Concerning the Relationship Between Creativity and Intelligence", Journal of Educational Research, 64(5), (June, 1971), 213-.

Edwards, M.P. and Tyler, L.E. "Intelligence, Creativity and Achievement in a Nonselective Public Junior High School", Journal of Educational Psychology, 56(2), (1965), 96.99.

Flescher, I. "Anxiety and Achievement of Intellectually Gifted and Creatively Gifted Children", Journal of Psychology, 56, (1963), 251-68.

Freeman, F.S. "The Lorge-Thorndike Intelligence Tests", The Fifth Mental Measurements Yearbook, The Grypon Press, Highland Park, New Jersey, 1959.

Getzels, J.W. and Jackson, P.W. Creativity and Intelligence, Wiley, New York, 1962.

Glass, G.V. and Stanley, J.C. Statistical Methods in Education and Psychology, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1970.

Goralski, P.S. "Creativity: Student Teacher Perceptions of Approaches to Classroom Teaching", Doctoral Dissertation, University of Minnesota, 1964.

Goulding, W.F. "A Preliminary Evaluation of the Process Oriented Elementary Science Curriculum Project (ESCP) in Newfoundland Schools", Unpublished Masters Thesis. Memorial University of Newfoundland, 1972.

Johnson, J.O. "The Relationship Between Science Achievement and Selected Student Characteristics", Science Education, 53(4), (1969), 307-18.

Kline, A.A. "Study of the Relationship Between Self-directed and Teacher-directed Eighth Grade Students Involved in an Open-Ended Supplementary ESCP Lab Block", Journal of Research in Science Teaching, 8, (1970-71), 263-71.

Lansdown, B. and Dietz, T.S. "Free vs. Guided Experimentation", Science Education, 49, (April, 1965), 210-.

Larin, O.E. The Prediction of Academic Achievement, Russell Sage Foundation, New York, 1965.

Lewis, R.D. and Bolzano, F.S. "Unstructured = Unorganized", Science Teacher, 38, (May, 1971), 58-9.

Lorge, I. and Thorndike, R.L. The Lorge-Thorndike Intelligence Tests Technical Manual for Administrators, Director of Testing and Research, Houghton Mifflin Co., Boston, 1962.

Osgood, C.E. and Suci, G. and Tannenbaum, P. The Measurement of Meaning, University of Illinois Press, Urbana, 1967.

Rainey, R.G. "Effect of Directed verus Non-directed Laboratory on High School Chemistry Achievement", Journal of Research in Science Teaching, 3, (1965-66), 286-.

Ray, W.E. "Pupil Discovery vs. Direct Instruction", Journal of Experimental Education, 29(3), (March, 1961), 271-80.

Shulman, L.S. and Keislar, E.R. Learning by Discovery, A Critical Appraisal, Rand McNally and Co., Chicago, 1966.

Torrance, E.P. Torrance Tests of Creative Thinking, Norms-Technical Manual, Ginn and Co., Toronto, 1966.

Tuckman, B.W. "Group Composition and Group Performance in Structured and Unstructured Tasks", Journal of Experimental Social Psychology, 3, (1967), 25-40.

Vernon, P.C. "Creativity and Intelligence", Educational Research, 6, (1964), 163-69.

Ward, J.H. Jr. "Multiple Linear Regression Models", Computer Applications in the Behavioral Sciences, Harold-Borko (ed.), Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1962.

Welch, W. "The Development of an Instrument for Inventorying Knowledge of the Processes of Science", Journal of Research in Science Teaching, 5, (1967-68), 64-68.

APPENDIX A

QUALIFICATIONS OF VALIDATORS

The validator must have

1. Taught children at the elementary school or prepared teachers to teach at that level.
2. Has been recommended by at least one member of professional rank of the Department of Science Education.

Either or both of

3. Has published or done research in science education.
4. Has worked with a curriculum project.

VALIDATION SCALE

Definition of scales:

Clarity:

1. UNCLEAR - needs major revision
2. CLEAR - but needs minor changes
3. CLEAR AS WRITTEN

Appropriateness in light of process tested:

1. INAPPROPRIATE - not worth including
2. APPROPRIATE
3. CRUCIAL - must be included

Difficulty with regard to age level:

1. VERY EASY
2. TOO DIFFICULT
3. APPROPRIATE

APPENDIX B

BALANCING - STRUCTURED STYLE

Activity I

<u>Purpose</u>: To compare the weights of a book, a pencil and two rocks without a balance.

<u>Materials</u>: For each student:
Various objects such as a book, a pencil, two rocks (of about the same weight).

<u>Instructions</u>: Pick up a book with one hand and a pencil with the other.
Which is heavier? ____________________
Then put down the pencil and pick up a rock. Which is heavier, the rock or the book? ____________________
Now put down the book and pick up the other rock. Can you tell which rock is heavier? ____________________

<u>Discussion</u>: The difficulty of telling which of two objects is heavier by subjective means when they weigh about the same.
The need for an instrument under these circumstances.

Activity II

<u>Purpose</u>: To make a number of balances.

<u>Materials</u>: For each pair of students:
Materials which students may use to construct balances: 12" rulers, hat pin (5"), soda straws, curtain rods, stiff wire and blocks.

<u>Instructions</u>: Take two of your books and place them about 3 inches apart. Now put a hat pin between the two books such that one end of the pin is on one book and the other end on the other book. Now put your ruler at the 6 inch mark on the pin. Is the ruler balanced? __________ How do you know it is balanced? __________
Now take your ruler and put it on the pin at the 5 inch mark. Is your ruler balanced now? __________
Why? ____
Take the soda straw and pierce the pin through it where you think is the middle of the straw. Place the pin with both ends on your books as before. Do you think the straw is now balanced? __________ Why? ____________________
Take some of the other things you've been given and try to make some balances.

Discussion: 1. Establishment of a balanced condition.
2. A seesaw balance.
3. Use of balance to weigh objects as in activity I.

Activity III

Purpose: To compare the weights of objects using a pegboard balance.

Materials: For each pair of students:
Pegboard balance (assembled and balanced)
Paper clips
Objects to be weighed with string attached.
A piece of wood, a big washer, a rock.

Instructions: Put a paper clip in hole # 8 on the left arm of the pegboard balance and put another clip in hole # 8 on the right arm of the balance. Hang one of the rocks on one of the paper clips and the piece of wood on the other paper clip. Which do you think is heavier, the wood or the rock? ________________
Now move the clip to which the rock is attached to the hole # 7. Which do you think is heavier now? ___________
Move the same clip to hole # 4. Which do you think is heavier now? ______________
Using this balance it seemed as if the rock was heavier at first but now it seems as if the wood is heavier. This cannot be right. It appears as if distance is important when weights are compared. When the wieghts of objects are compared using this balance they must be at the same distance from the center.
Now put one clip in hole # 7 of the right arm and another clip in hole # 7 of the left arm. Attach the rock to one and the wood to the other. Which is heavier? ___________
Remove the rock and attach a big washer. Which is heavier the rock or the washer? _____________
Then arrange the rocks, the wood and the washer in order of weight with heaviest first and the lightest last.

Discussion: When comparing the weights of objects using a pegboard balance it is important to have the distance from the center equal.

Activity IV

Purpose: To find out what factors are important when trying to balance the arms of a pegboard balance.

Materials: For each pair of students:
A pegboard balance
Paper clips
Big washers

Instructions: To a paper clip put in the hole # 3 on the right arm of your blance hang three washers. Put three washers on a paper clip and attach it to the left arm, such that the left and right arm balances. Note that this is similar to the last acitivty. What can you say about trying to balance equal number of washers on each arm using a pegboard balance? ____________________
To a paper clip put in hole # 5 on the right arm of your balance hang 3 washers. Put 5 washers on a paper clip and attempt to balance the right arm by putting the clip in a number of holes in the left arm. Where did the clip have to be put in the left arm to balance the right arm containing 3 washers in hole # 5? ____________________
To a paper clip put in hole # 1 on the right arm of your balance hang 6 washers. Put 3 washers on a paper clip and attempt to balance the right arm by putting the clip in a number of holes in the left arm. Where did the clip have to be put in the left arm to balance the right arm containing 6 washers in hole # 1? ____________________
What therefore, are the two factors or variables that you look at when you are trying to balance the two arms?

Discussion: The need to consider both weight and distance when trying to balance both arms of a pegboard balance.

Activity V

Purpose: To use a pegboard balance to find out if there is any relationship between the weight and distance on the right arm and the weight and distance on the left arm when these arms are balanced. To try some more examples to test this relationship.

Materials: For each pair of students:
Pegboard balance
Big washers
Paper clips

Instructions: Put 4 washers on a paper clip and hang the clip through hole # 4 on the right arm of your pegboard balance. Try to balance the right arm by hanging different numbers of washers to a clip and attaching to the left arm. Complete the following table:

Left Arm		Right Arm	
Hole #	# of washers	Hole #	# of washers
	4	4	4
	8	4	4
	2	4	4
	16	4	4

Remove the clip and washers from the left arm of your balance and just take off the washers from the right arm. Keep the clip in hole # 4 in the right arm of your pegboard balance but this time keep changing the numbers of washers that you are attaching, as indicated in the table below. Each time you change the number of washers on the right arm try to balance this arm by putting 4 washers on a paper clip and hanging it from one of the holes in the left arm.
Complete the following table:

Left Arm		Right Arm	
Hole #	# of washers	Hole #	# of washers
	4	4	1
	4	4	2
	4	4	8
	4	4	6

Look at both tables that you completed.

What relationship can you see between the values of weight (in washers) and length for the right arm and the weight (in washers) and length for the left arm? ______________________________

Take your washers and clips and see if your relationship holds in some more cases. Write the relationship which seems to hold in symbols.

<u>Discussion</u>: Reinforce the relationship of balanced conditions. Establishment of the proper symbolic representative.

BALANCING - UNSTRUCTURED STYLE

Activity I

Purpose: To compare the weights of a book, a pencil, and two rocks without a balance.

Materials: For each student:
Various objects such as a book, a pencil, and two rocks (of about the same weight).

Instructions: On your desk you will find the objects listed above. Try to compare the weights of the objects without using a balance.

Activity II

Purpose: To make a number of balances.

Materials: For each pair of students.
Materials which students may use to construct balances: 12" rulers, hat pin (5") soda straws, curtain rods, stiff wire and blocks.

Instructions: On your desk you will find the objects listed above. Try and make as many balances as you can using these objects.

Activity III

Purpose: To compare the weights of objects using a pegboard balance.

Materials: For each pair of students:
Pegboard balance (assembled and balanced)
Paper clips
Objects to be weighed with string attached.
A piece of wood, a big washer, a rock.

Instructions: You are given a pegboard balance and two paper clips which are to be put in the holes of the balance arms on which you are meant to hang the objects listed above.
Use this balance to arrange these objects from the heaviest to the lightest.

Activity IV

<u>Purpose</u>: To find out what factors are important when trying to balance the arms of a pegboard balance.

<u>Materials</u>: For each pair of students:
A pegboard balance
Paper clips
Big washers

<u>Instructions</u>: Using your pegboard balance, paper clips and washers, try to balance the left and right arm of your pegboard balance by putting equal number of washers on each arm. Then try to balance the left and right side with unequal number of washers.

Activity V

<u>Purpose</u>: To use a pegboard balance to find out if there is any relationship between the weight and distance on the right arm and the weight and distance on the left arm when these arms are balanced.
Try some more examples to test this relationship.

<u>Materials</u>: For each pair of students:
Pegboard balance
Big washers
Paper clips

<u>Instructions</u>: Using your pegboard balance, washers and paper clips try to find out if there is any relationship between the weight and length on the right arm and the weight and length of the left arm when these arms are balanced.

ACHIEVEMENT TEST 1 - BALANCING

1. Look carefully at the diagram below

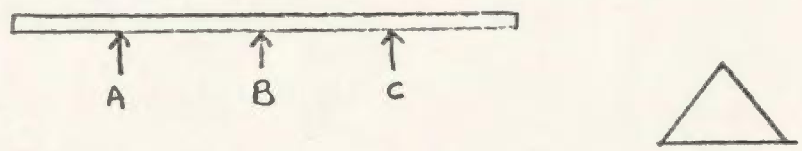
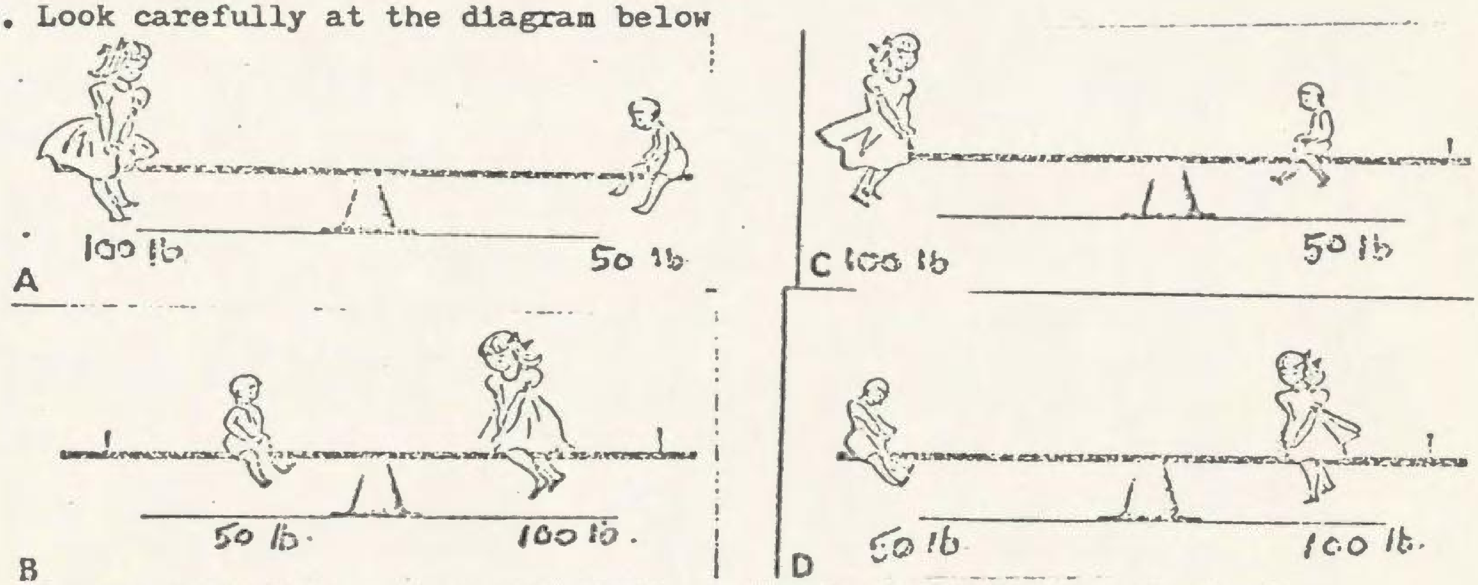


Diagram 1

Diagram 1 shows a stick of the same thickness along. Also shown is a wooden triangle. Check the best position for the block such that the stick would be balanced.

A____________
B____________
C____________

2. Look carefully at the diagram below



George wanted to seesaw with Betty. Which picture shows the best way for Betty who weighed 100 pounds to balance George who weighed 50 pounds? Check the best way.

A____________
B____________
C____________
D____________

3. Look carefully at the diagrams below in which objects are balanced with the same size weights.

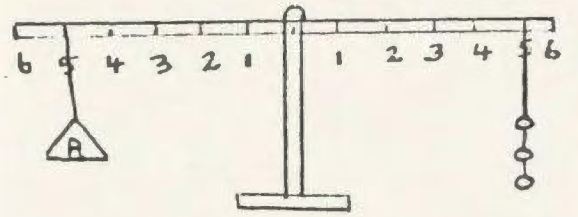


Diagram 3

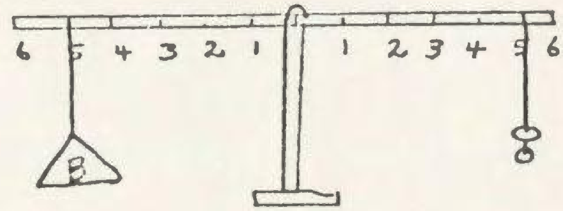


DIAGRAM 4

Check whether you think object A or B is heavier.
Object A ________
Object B ________

4. Look carefully at the diagrams below in which objects are balanced with weights.

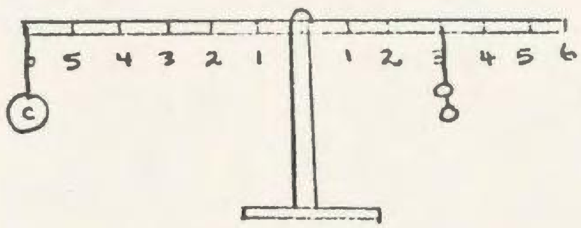


DIAGRAM 5

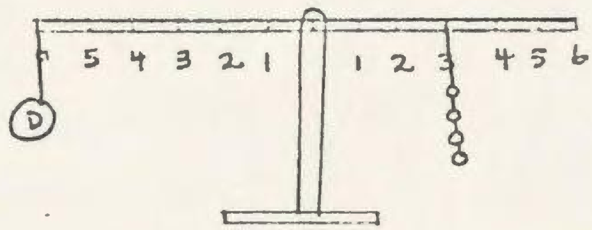


DIAGRAM 6

Check whether you think object C or D is heavier.
Object C ________
Object D ________

5. Look carefully at the diagram below in which two objects are balanced.

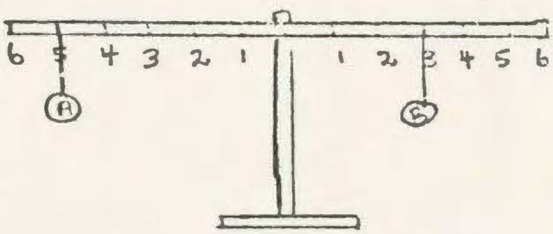


DIAGRAM 7

Underline what you believe to be the right answer.
1. A is heavier than B
2. B is heavier than A
3. A and B have the same weight
4. Cannot tell from information given

6. Look carefully at diagram 8 below. Check whether the arms are balanced or not balanced.

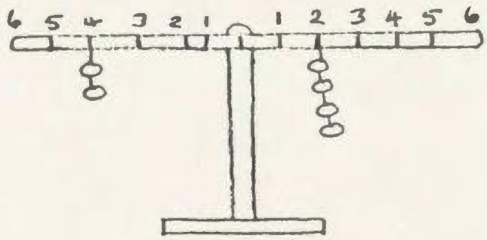


Diagram 8

Balanced __________
Unbalanced __________

7. Look carefully at diagram 9 below. Check whether the arms are balanced or not balanced.

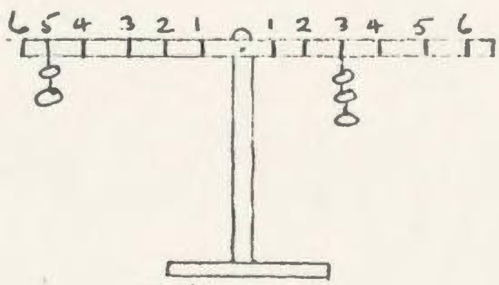


Diagram 9

Balanced __________
Unbalanced __________

8. Look carefully at diagram 10 below.

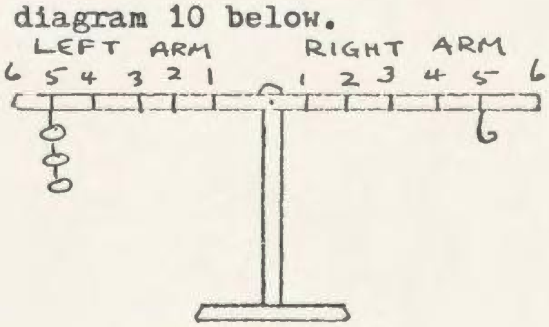


Diagram 10

3 big washers are hooked on a paper clip and put in hole # 5 of the left arm of a pegboard balance. How many big washers on a paper clip in hole # 5 of the right arm are necessary to balance the left?

Put your answer here ____________________

9. Look carefully at the diagram below.

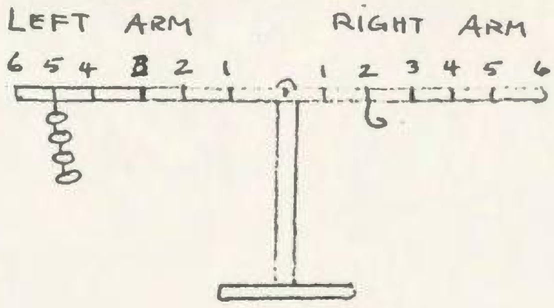


DIAGRAM 11

4 big washers are hooked on a paper clip and put in hole # 5 of the left arm of a pegboard balance. How many big washers on a paper clip put in hole # 2 of the right arm are necessary to balance the left?

Put your answer here ______________________

10. Look carefully at the diagram below.

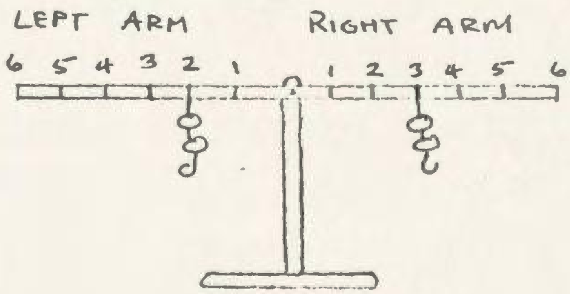


DIAGRAM 12

Where would you hang a single washer in the above diagram in order to balance the left and the right arms? Draw in the single weight in its proper position in the diagram.

11. Refer to the diagram below.

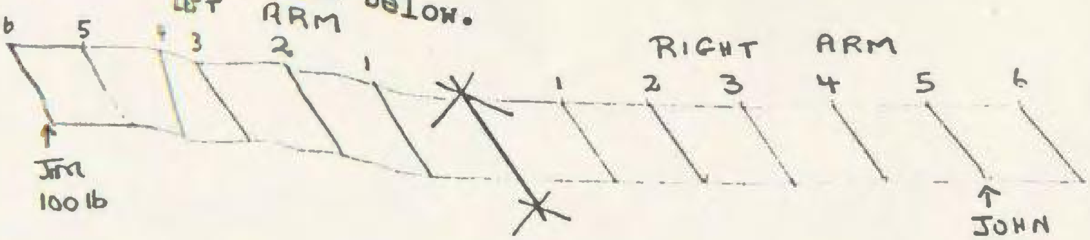


DIAGRAM 13

Jim and John are using a ladder as a seesaw. Jim, who weighs 100 pounds is sitting on bar 6 on the left side of the center. John who weighs 150 pounds is sitting on bar 5 on the right side of the center. The right and left sides are not balanced. To which bar does John have to move to balance Jim on bar 6?

Put your answer here ____________________

12. A student tried to find the relationship between the weights of three objects A, B, and C by using a pegboard balance. Look at the following diagrams and write down what you believe to be this relationship. i.e. which object is heaviest, which object is the lightest and which object has a weight between the other two?

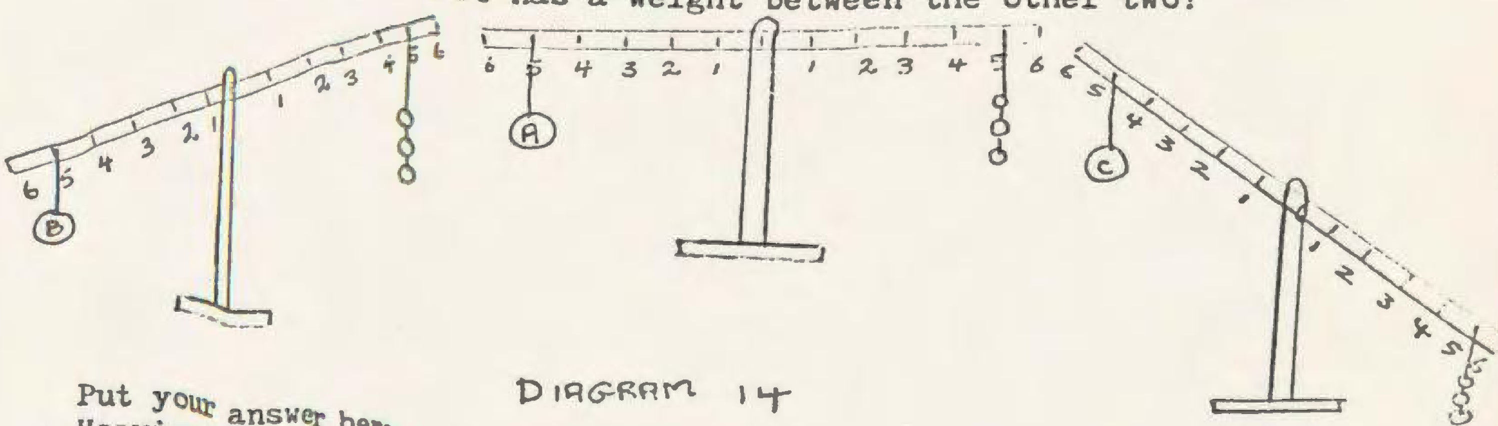


DIAGRAM 14

Put your answer here
Heaviest ________
Next ________
Lightest ________

13. Look carefully at the diagram below.

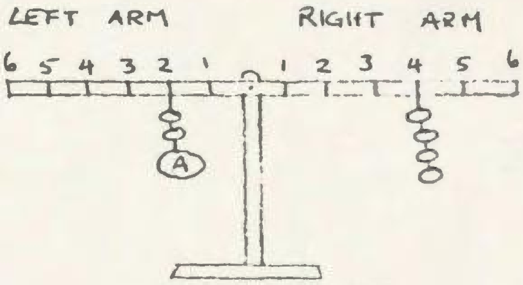


DIAGRAM 15

On the left arm of the balance two washers and object A are hooked in hole # 2. On the right arm 4 washers are hooked in hole # 4. The arms are balanced. What is the weight of object A in units of washers?

Write your answer here ____________________

14. Look carefully at the diagram below.

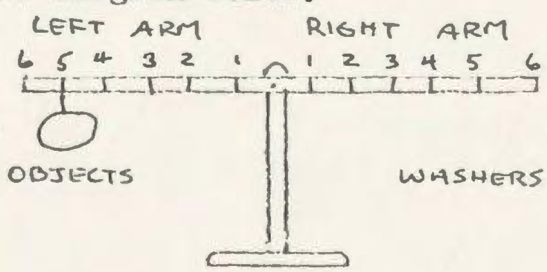


DIAGRAM 16

Two objects are hooked on paper clip and put in hole # 5 of the left arm of a pegboard balance. Washers are hooked on a paper clip and put in holes of the right arm of the balance. The following information is obtained.

Object	Weight in washers	Hole # of Washers
A	1 large washer	5
B	3 small washers	3

Underline what you believe to be correct.

1. A is heavier than B
2. B is heavier than A
3. A and B have the same weight
4. Cannot tell from information given

15. A student tried to determine the relationship between the weights of big and small washers. Refer to the diagrams and table of information to determine this relationship.

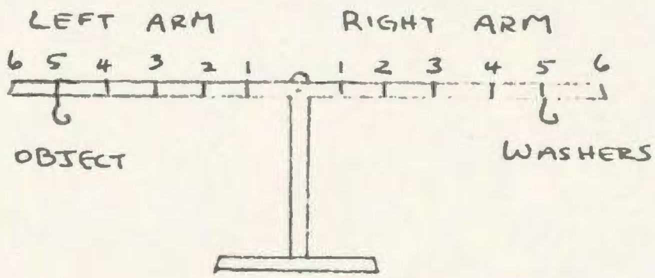


DIAGRAM 17

Left Arm			Right Arm	
Object	Hole #	Large Washers	Small Washers	Hole #
A	5	4	0	5
B	5	0	12	5

The weight of object A = the weight of object B.
Write what you believe to be the relationship between the weight of a large and small washer here.

____

DENSITY-VOLUME - STRUCTURED STYLE

Activity I

Purpose: To describe what happens when liquids are placed into other liquids.

Materials: Each pair of students should have
4 medicine cups of liquid
medicine dropper
styrofoam tray

For the class
paper towels
newspapers

Instructions: Notice that you have 4 medicine cups of different liquids. With your medicine dropper, place a drop of the red liquid into each of the other liquids, and watch to see whether it floats or sinks. Fill in the following table.

Color of liquid	What happens when the red liquid is put in
green	________________
clear	________________
blue	________________

Discussion: 1. When one liquid sinks in another, what does this mean in terms of the relative weights? What does it mean when it floats?
2. If you put liquid A into liquid B and it sinks, what will happen if you put liquid B into liquid A?

Activity II

<u>Purpose</u>: To compare the density of salt and fresh water.

<u>Materials</u>: Each pair of students shaould have
3 medicine cups
medicine dropper
styrofoam tray

For the class
food coloring kit
paper towels
newspapers

<u>Instructions</u>: Take one medicine cup of fresh water and one of salt water, making sure that the same amount of water was in each one. Do you think that there is any difference in the weight of the water in the two medicine cups?
Using your medicine dropper, put one drop of red food coloring into the medicine cup of salt water. <u>DO NOT STIR</u>. Observe what happens. Now put one drop of red food coloring into the cup of fresh water. <u>DO NOT STIR</u>. Did the same thing happen in both cups? What do you think would happen if you put a drop of salt water in some fresh water?
Place a drop of the red-colored salt water into a medicine cup of clear, fresh water. What happens? Is it caused by the salt or the coloring? To find the answer, take another cup and put into it a drop of colored fresh water, what happens?

<u>Discussion</u>:
1. Does the salt water sink in fresh water?
2. Do equal amounts of salt and fresh water weigh the same?
3. How does the color spread?

Activity III

Purpose: To determine if there is a relationship between weight and density.

Materials: Each pair of students should have
Medicine cup full of each of the four basic liquids
Styrofoam tray
Medicine dropper

Instructions: Each of the four liquids have been weighed by the teacher and the weights were found to be

Liquid	Number of washers needed
A	3
B	2
C	4
D	1

Using your medicine dropper, place a drop of liquid A into liquid B. Observe whether it sinks or floats. Do the same thing using liquid C and D, and put the results in the table.

Liquid A into liquid B	________
Liquid A into liquid C	________
Liquid A into liquid D	________

Discussion: 1. What does it mean when one liquid floats on another?
2. Why was it necessary to use the same amount of liquid when you weighed them?
3. What is density?

Activity IV

Purpose: To describe what happens to the volum and weight of two objects when they are mixed together.

Materials: Each pair of students should have
marbles
BB's
sand
bottle

Instructions: Place the BB's in the bottle. Measure the height in the bottle, and note the weight.
Now place the marbles on top of the BB's, and measure the total height and note the weight. Put the results in the table.

	Height	Weight
BB's	____	4 washers
marbles and BB's	____	10 washers
Now mix the marbles and the BB's	____	
marbles and BB's (after mixing)	____	10 washers

Now repeat the same procedure using the same amount of BB's and, instead of marbles, an amount of sand weighing 8 washers.

	Height	Weight
BB's	____	____
Sand and BB's	____	____
Sand and BB's (after mixing)	____	____

Discussion:
1. Is the weight of the mixture changed after mixing?
2. Will the changes in volume occur with all sizes of particles?
3. Is there any relationship between the size of particles and the amount of volume reduction?
4. Is this the 'true volume'?

Activity 5

<u>Purpose</u>: To describe how you would find the 'true volume' of a granular solid and to describe what happens to the 'true volume' when you mix it with another granular solid.

<u>Materials</u>: Each pair of students should have
styrofoam cup
granular solids (Beans and Stones)
medicine cup
styrofoam tray

<u>Instructions</u>: Remember the last activity where two things were mixed. What happened to the volume when you shook the container? Now measure the number of medicine cups of stones you have. Put the stones into the styrofoam cup. Find out how many medicine cups of water you must pour in so as just to cover the stones. Now subtract the volume of the water from the volume of the stones and you will have the 'true volume' of the stones.
Do the same thing with the beans as you did with the stones and you will find the 'true volume' of the beans.
You now know the 'true volume' of the beans and stones. Now mix the beans and stones and find the 'true volume' and compare it to the 'true volume' of the objects taken separately.

<u>Discussion</u>:
1. Does the water fill the spaces between the stones better than the BB's did in the last activity?
2. Why is water a better substance to use in finding the 'true volume' than, say, BB's?
3. Is the sum of the true volume of the beans and stones the same as the true volume when they are mixed?

DENSITY-VOLUME - UNSTRUCTURED STYLE

Activity I

Purpose: To describe what happens when liquids are placed in other liquids.

Materials: Each pair of students should have
4 medicine cups of liquids
medicine dropper
styrofoam tray

For the class
paper towels
newspapers

Instructions: After obtaining a medicine cup of each of the colored liquids, find out which of the liquids is the heaviest and which is the lightest.

Discussion:

Activity II

Purpose: To compare the density of salt and fresh water.

Materials: Each pair of students should have
3 medicine cups
medicine dropper
styrofoam tray

For the class
food coloring kit
paper towels
newspapers

Instructions: Using the materials, find out what happens when salt water is mixed with fresh water, and try to find the heaviest or the most dense.

Discussion:

Activity III

Purpose: To determine if there is a relationship between weight and density.

Materials: Each pair of students should have
medicine cup of each of the four liquids
equal arm balance
washers
styrofoam tray
medicine dropper

Instructions: Compare the weight of the liquids to whether or not they float or sink in another liquid.

Discussion:

Activity IV

Purpose: To describe what happens to the volume and weight of two objects when they are mixed together.

Materials: Each pair of students should have

marbles
BB's
sand
bottle

Instructions: Compare the total volume of a mixture to the sum of the volume of the objects taken separately.

Discussion:

Activity V

Purpose: To describe how you would find the 'true volume' of a granular solid and to describe what happens to the 'true volume' when you mix it with another granular solid.

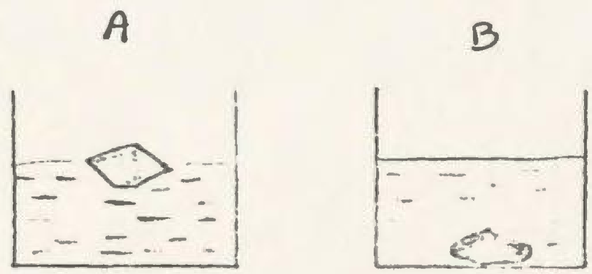
Materials: Each pair of students should have
- styrofoam cup
- granular solids (Beans and Stones)
- medicine cup
- styrofoam tray

Instructions: Using water, instead of BB's like you did yeaterday, find the 'true volume' of the stones and beans. Then compare the sum of the 'true volumes' of the stones and beans with their 'true volume' when they are mixed.

Discussion:

ACHIEVEMENT TEST II - DENSITY AND MIXTURES

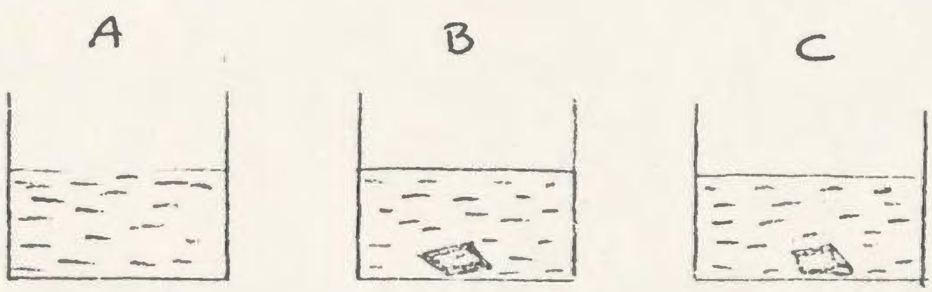
1. Students are required to put a check mark (✓) in the space before the answer of their choice.



In the picture you see two jars of liquid. The object in each jar is the same size and weight. Which of the following could you say about the difference between the liquids in jar A and B?

_____1. Liquid in jar B is heavier than liquid in A
_____2. The liquids are the same in both jars
_____3. Liquid in jar B is lighter than liquid in A

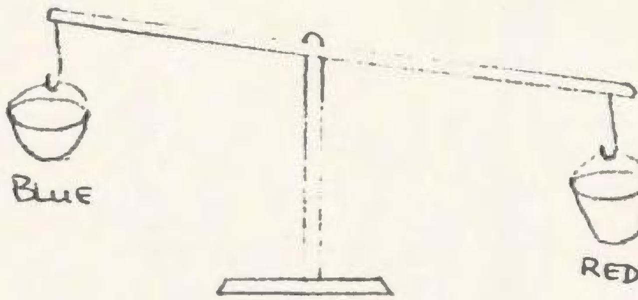
2.



If the object in Jar A were removed and placed into another jar, which we can call jar C, and the object sank, we could say that

_____1. The object in jar C is heavier than object in B
_____2. The liquid in jar C might be the same as in jar A
_____3. The liquid in jar B might be the same as in jar C

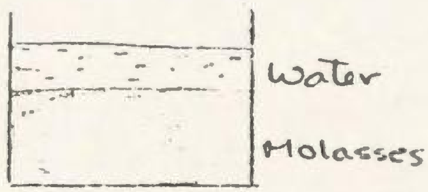
3.



If there is 1 cup full of red liquid and 1 cup full of blue in the containers shown in the diagram, then from looking at the diagram you can say that

_____1. The blue liquid is denser than the red
_____2. Equal amounts of the two liquids are not the same weight
_____3. The two liquids weigh the same

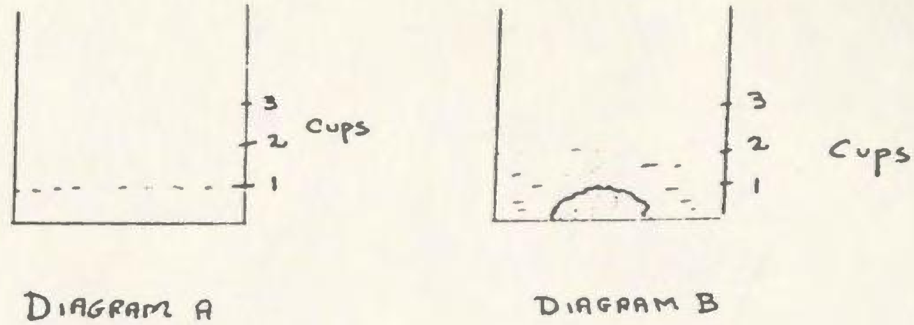
4.



If you have a jar, like in the diagram, which has some molasses on the bottom and some water on the top of the molasses, what do you think would happen if you placed an object, that was just heavy enough to sink in the water, in the jar?

_____1. It would sink in the water and in the molasses
_____2. It would sink in the water but float on the molasses
_____3. It wouldn't sink in either liquid

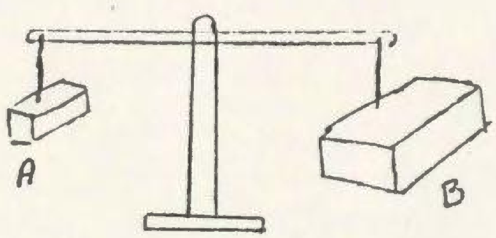
9.



If you have a vial with 1 medicine cup of water in it, as in diagram A, and then put some sand in it bringing the level of the water up to 2 medicine cups, as in diagram B, what is the true volume of the sand?

_____1. 3 cups
_____2. 1 cup
_____3. 2 cups

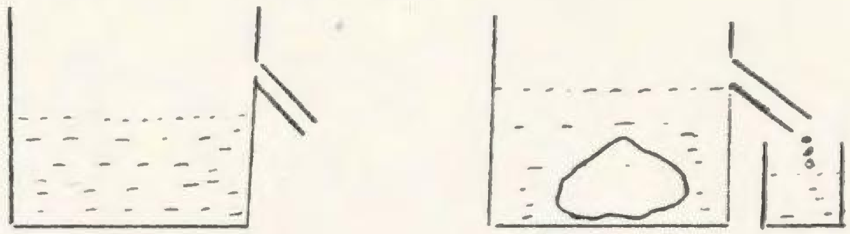
10.



You will note from the diagram that even though object A is much smaller than object B, it is still balanced. What can you say about the density of A as compared to B?

_____1. A is more dense than B
_____2. B is more dense than A
_____3. A is less dense than B

11.



If you have a container filled up to the spout with water, and you then place a rock into the container, some of the water will overflow. If you collected this water in another container, what can you say about the volume of the rock with respect to the collected water?

_____1. volume of the rock is more than the volume of the water collected
_____2. volume of the rock is the same as the volume of the water collected
_____3. volume of the rock is less than the volume of the water collected

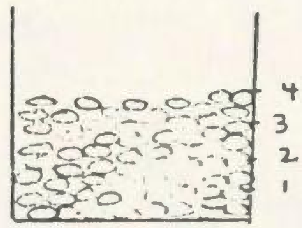
12. Look back at the diagram in number 11. What would happen to the volume of the water in the little container, if you had used an object that was the same size, but much denser?

_____1. the volume of the water would be the same
_____2. the volume of the water would be more
_____3. the volume of the water would be less

13. Look back at the diagram in number 11 again. If you had weighed the water in the small container, and weighed the rock, which of the following could be said about the weight of the water and the rock?

_____1. the weight of the water is more than the weight of the rock
_____2. the weight of the water is the same as the weight of the rock
_____3. the weight of the water is less than the weight of the rock

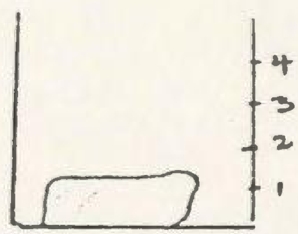
14.



If you measure out 4 cups of peanuts and put them into a container as shown in the diagram, and you know that the "true volume" of the peanuts is only 2 cups, how much water must you pour into the container to just cover the peanuts?

_____1. 3 cups
_____2. 2 cups
_____3. 1 cup

15.



Now instead of peanuts, suppose you had 1 large candy. The "true volume" of the candy is 2 cups. If you now pour into the container 2 cups of water, what will the total volume of the mixture be?

_____1. 2 cups
_____2. 3 cups
_____3. 4 cups

PREFERENCE INSTRUMENT

NAME ______________________ SCHOOL ______________________

Read each statement carefully and place a check mark ( ) in the blank underneath the name of the activities that applies best to the statement.

	Balancing	:	Liquids
1. During which set of activities did you feel more relaxed?	________	:	________
2. Which set of activities did you find better?	________	:	________
3. Which set of activities did you find more confusing?	________	:	________
4. What were the more pleasant activities?	________	:	________
5. In which activities did you learn more?	________	:	________
6. Which was the harder set of activities?	________	:	________
7. Which activities were more exciting?	________	:	________
8. What was the worse set of activities?	________	:	________
9. What activities were the more useful?	________	:	________
10. During which activities were you more clear about what you were doing?	________	:	________