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ROJAS C., CARLOS ARMANDO

A STUDY OF THE EFFECT ON FREQUENCY OF TESTING UPON THE MEASUREMENT OF STUDENT ATTITUDES TOWARD SCIENCE CLASS AND MEASUREMENT OF ACHIEVEMENT ON A CRUSTAL EVOLUTION UNIT USING A TIME-SERIES DESIGN

The Ohio State University

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DISSERTATION

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

By
Carlos A. Rojas C, B.Ed., M.A.

** * * * *

The Ohio State University
1979

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To my parents, Martin and Maria,

who I have neglected for so many years.

Their sacrifices, patience, encouragement,

and trust made it all possible.
To my parents, Martin and Maria,
who I have neglected for so many years.
Their sacrifices, patience, encouragement,
and trust made it all possible.
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CHAPTER I
INTRODUCTION

Over the past decade or two, many science educators have conducted studies on curriculum, learning theory, and instructional procedures as they applied to science teaching. An often-used design requires an experimental group which is pretested, then a treatment is introduced followed by a post-test. Frequently a control group has been added to the design. Scores on the post-tests are compared to those obtained previous to the treatment, if differences are found to be statistically significant, they are attributed to treatment effects. The most common techniques used to determine statistical significance are t-tests, analysis of variance, and analysis of covariance.

There seems to be a common "deficiency" in today's studies. After reviewing research studies dealing with concept learning, Voelker (1973) stated that "...when the study is completed do we know whether the students had difficulties with the attributes or the examples of the concepts, or do we only know that they did not fare too well on the final examination?..." (p. 41). The answer is obvious, we know only how the students performed on the final examination. Since the designs used only provide post-test scores, the researcher can only assess final outcomes.
If researchers in science education are to be concerned with learning patterns or attitude changes throughout time, and factors that affect them, we ought to look for designs which will enable us to monitor students' attitudes and patterns of learning on a frequent basis. A design described by Campbell and Stanley (1963) that employs the collection of data at several points is the time-series design. This design is characterized by observations obtained either periodically or continuously. In behavioral sciences time-series designs have been used with timidity. In managerial and business forecasting areas, however, these designs have been widely and successfully used for several decades (Nelson 1973, Box and Jenkins 1970).

A time-series design implemented in an educational setting can facilitate the close monitoring of patterns of learning or attitude changes over relatively "long" periods of time. The smaller the interval between observations the better the chances of detecting possible changes which may otherwise be overlooked by the investigator. Mayer and Lewis (1979) describe an intensive time-series design as one in which data are collected every day. The authors developed a semantic differential instrument to assess students' attitudes toward a biology class. Data were collected daily five minutes prior to the end of the class. This procedure was followed for eight weeks. Attitude data were then plotted. A repetition of patterns was observed when the same teaching methods were used in the biology class, indicating the consistency or reliability of the instrument. Since the outcomes obtained with the instrument were also consistent with those reported
elsewhere in the literature, the authors concluded that the instrument had concurrent validity.

In an attempt to daily assess understanding of crustal evolution, Mayer and Kozlow (1979) used a multiple-group—single-intervention time-series design. The authors were confronted with the need for an instrument which could be administered in three or four minutes and still be reliable. They developed a one-item multiple-choice instrument, and a three-item multiple-choice instrument. It was found that scores on the one-item instrument better depicted a "learning curve" than the scores obtained with the three-item instrument. The data collection procedure used in this "intensive" design was effective, without disturbing the normal daily routine of the students.

An indirect use of an intensive time-series design can be found in Weinstein's (1976) study of the effects that environmental changes in a classroom had upon student behaviors. The author observed each of the 25 members of a "second-third informal classroom" six times every day for four weeks. This study required observations at relatively short periods of time. The subjects, however, did not respond to any instruments. Thus, frequency of testing or instrumentation were not "threats" to the internal validity of the design.

**Need For Study**

Traditional designs aimed at assessing students' achievement or attitudes can only provide limited knowledge regarding these variables. An intensive time-series design on the other hand enables the researcher to measure students' performance and attitudes on a
frequent basis, and the relationship between these and factors affecting
the classroom.

In those instances in which observations are collected intensively
by the researcher without the direct participation of the students, the
time-series design has proved to be a powerful tool for close monitoring
of students' behaviors. However, in those cases in which students are
"directly" involved in responding to instruments, negative or apathetic
postures may stem from the fact that repeated measurements are taken
over "long" periods of time. If so, unreliable data may result.

Even though this design has shown to be valuable when used in
educational settings, a major concern has arisen from the studies
conducted by Mayer and Lewis (1979), and Mayer and Kozlow (1979).
Frequency of testing may create an adverse reaction toward the
instrument or the treatment. Cook and Campbell (1979) refer to this
threat as "resentful demoralization" which militates against internal
validity of the design. If this is the case it should be reflected on
the students' attitude pattern throughout time. Frequency of testing
may also enhance achievement due to the fact that students' familiarity
with the instruments may increase with time, thus threatening also the
validity of the design.

Serious concerns therefore surround the validity of "intensive"
time-series designs used in an educational setting in which students'
responses are required.
Problem Statement

Does frequency of testing affect the measurement of student attitudes toward science class and the measurement of achievement on a crustal evolution unit when employed in a study using an intensive time-series design?

Hypotheses

1. Students' mean performance on the crustal evolution unit will be similar regardless of the testing schedule.

2. Students' mean attitudes toward "today's science class" will be similar regardless of the testing schedule.

3. There will be a significant change in achievement during the intervention period followed by a down trend in achievement during the follow-up period.

4. The students' attitude pattern toward today's science class will be similar throughout the study.

Assumptions

1. A multiple-choice paper and pencil instrument can be used to assess achievement on crustal evolution.

2. A semantic-differential paper and pencil instrument can be used to assess attitudes toward the science class.

Limitations

1. The study will be conducted during six weeks.

2. The students will be from the eighth-grade earth-science class
at a suburban junior-high school.

3. The concept to be taught during the intervention period is crustal evolution.

Definition of Terms

1. **Achievement.** Performance on a multiple-choice instrument.
2. **Baseline.** In a time-series design this is the period of time during which data are collected prior to the intervention.
3. **Crustal Evolution.** As used in Stoever's report (1974, p. 1) crustal evolution "encompasses the theories of continental drift, polar wandering, sea floor spreading, and plate tectonics."
4. **Drift.** In a time-series design this is the "constant rise or fall of a series" (Glass et al., 1975, p. 14).
5. **Item Difficulty.** Percentage of students missing the item.
6. **Follow-up.** Period of time after the intervention is withdrawn.
7. **Intervention.** In a time-series design, this is the period when changes are introduced.
8. **Level.** A series may oscillate around a mean level. This level can be changed due to the intervention effects.
9. **Model-ARIMA.** Mathematical representation of a time-series process.
CHAPTER II
REVIEW OF RELATED LITERATURE

This section has been divided into two major parts. The first part focuses on research dealing with the testing effects found when repeated measurement techniques have been used. The second part is devoted to studies in which time-series designs have been used. The latter part also reviews some studies dealing with the appropriateness of time-series analysis as compared to ANOVA or t-test techniques.

Testing Effects

Studies grouped under "testing effects" can be broadly classified as dealing with two major areas: (1) The effects of testing upon measurement of achievement, and (2) The relationship between testing-retesting and the anxiety and attitudes of the subjects.

Researchers have felt uncomfortable when repeated measurements have been the only viable way to assess research problems. Campbell and Stanley (1963) cited research studies in which the effects of pre-testing upon final outcomes were studied. The authors considered the possible sources that may affect the validity of experimental as well as quasi-experimental designs. History, maturation, testing, and instrumentation are some of the sources affecting the internal validity.
of the designs. As to external validity of time-series designs, Campbell and Stanley (1963, p. 41) say: "...it is clear that the experimental effect might well be specific to those populations subject to repeated testing. This is hardly likely to be a limitation in research on teaching in schools, unless the experiment is conducted with artificial observations not common to the usual school setting."

In regard to repeated measurements, Solomon in 1949 stated his concerns regarding the use of pre-tests in experimental settings. The author stated that the simple fact of taking a pre-test affects the subjects' attitudes toward the treatment procedures. He found that pre-testing had a negative effect upon the final outcomes of an experiment aimed at teaching spelling.

When repeated measurements are necessary, a major concern among scholars is the role that the anxiety created by the testing procedures may have upon the students' outcomes. Mann et al (1970) studied the effects of serial retesting on the relative performance of seventh-grade students. Three parts of the Academic Promise Test (APT), numerical, language usage, and verbal tests were administered to seventh graders who were classified as high or low-test anxious. The testing was conducted four times at one-week intervals. The authors concluded that gain scores were due to the fact that the students were simply learning from "retest taking." They emphasized the fact that no feedback was provided to the students. More significant improvements were reported in the area of numerical aspects than in the verbal section of the APT test. None of the testing-time-by-anxiety-interactions were significant, consequently the authors rejected the
hypothesis that high-anxiety students would improve their position relative to low-anxiety students on later trials.

Finally, it was observed that the greatest gains were pursued between the first and second testing schedules. This finding supports the studies of George (1965), and of Fiske (1957). In general the last two studies found that when retesting is present, the agreement between the first two outcomes is lower than at any other testing times. Fiske (1957, p. 461) concluded that "...more responses are changed from first to second testing than between any other serial pair."

Lane, Pen, and Fisher (1966) administered two forms of the Miller Analogies Test (MAT) to 84 undergraduates who were retested (once a year) from 1960 to 1964. The MAT test is used for graduate school candidates at the University of Wisconsin. The two forms as reported by the MAT manual are almost equivalent, since differences in mean and standard deviations are insignificant. The authors found significant gains in the retest scores. They conclude that "...substantial practice effect has occurred, or that one form is more difficult than the other" (p. 410).

Catanzano and Wilson (1977) studied the effect of three retesting contingencies upon achievement, anxiety, and attitudes in seventh grade science. The three alternatives used were: no retesting, optional retesting, and mastery retesting. Three intact classes were randomly assigned to one of the three testing schedules. During six weeks, each group was tested. The optional retesting group was allowed to take one equivalent test if they desired, the mastery retesting group was required to take tests until a mastery of 80 percent was achieved. The
authors pointed out that each class had the same teacher, covered the same topic, and reviewed the test and items one day after the test had been administered. The mastery contingency and the optional retesting groups showed significant gains for the content-free answers as compared to the no retesting group. There were no significant differences between the mastery retesting and optional retesting groups. The authors also administered an anxiety and attitude scale the third day before the last week of the study. "...anxiety toward testing was not differentially affected by the testing contingencies" (p. 178). It was also found that attitudes toward school, science, and retest were significantly better for students in the optional retesting schedule than for those in the mastery retesting schedule. The authors finally concluded that the data supported earlier studies claiming that retesting (mastery or optional) influences student achievement and attitudes.

Summary

Most of the studies dealing with repeated measurements were characterized by the use of the same instruments or equivalent forms. In most instances, instruments consisted of multiple-choice items. Some studies (Lane et al., 1966; Mann et al., 1970) used standardized tests to assess students' achievement. In Lane's study there was a powerful variable added to the study: the fact that the performance on the MAT test influenced the students' admission to graduate school.
From this review one can see that precautions should be taken to avoid, or at least reduce, the effects of extraneous variables (learning from testing-anxiety) when repeated measurements are part of the design. In the section devoted to methodology the reader will find the precautions already taken in this study.

The studies summarized indicate that retesting procedures increased learning. Similarly the studies dealing with attitudes agreed on the fact that attitudes toward school, class, or treatment, were lowered due to the retesting procedures.

**Time-Series**

A review of the literature on time-series may well be considered as a glance at the fields of economics, business, behavioral sciences, and mathematics. Box and Jenkins (1970) and Nelson (1973) are considered excellent reference sources for forecasting and managerial problems, whereas Glass, Willson, and Gottman (1975) published one of the few time-series related references applied to behavioral sciences. Their book can be considered as a practical application of Box' theories and models to behavioral sciences.

Gottman, McFall, and Barnett (1969) published a paper aimed at presenting time-series methodology to the social sciences. In their report, they presented time-series as a descriptive, heuristic, quasi-experimental design plausible when control groups are not suitable. Two techniques for analyzing time-series are described: (1) The curve-fitting technique is described, and (2) The generating function approach which involves the use of moving average or autoregressive processes.
Time-series designs have been used as an aid in curriculum evaluation (Padia and Smith, 1974; Fox, 1975). Changes in behavior and attitudes have also been assessed with time-series. (Schnelle and Lee, 1974; Weinstein, 1976; Mayer and Lewis, 1979).

Padia and Smith (1974) used a single-intervention time-series design with four different groups to study the effects of a field camp program in Colorado, upon the following variables: self-esteem, self-awareness, self-assertion, and acceptance of others. A unit-replicative, stratified group single-intervention design was used.

\[ \text{0000X0000} \]
\[ \text{0000000000X0000} \]
\[ \text{000000000000000X0000} \]

Where 0 = Observations.

X = Intervention.

All of the series were identified as second-order moving-average. (Moving average processes are described by Glass, Willson, and Gottman, 1975, and Box and Jenkins, 1970). Tests for significant changes in level were conducted using a computer program (TSX) developed by Bower, Padia, and Glass (1975). Two of the three series showed significant changes in level for both the self-assertion, and the self-esteem scales.

Fox (1975) used a single-group—multiple-intervention time-series design as an aid for program evaluation. The study was designed to evaluate the impact of a one-month training event upon student-teacher participants in a "Corps Member Training Institute" (CMTI). The design used can be represented as follows:
Five professional perspectives were the focus of the study: teaching as a technique, teaching as curriculum design, teaching as student personal development, teaching as community involvement, and teaching as organizational behavior. The study also focused on the participants' perspectives toward the nature of the internship, the nature of the teaching, reasons for school success, reasons for school failure, and expectations for CMTI and the internship. Time series models were identified based upon the autocorrelation coefficients obtained from the computer program "CORREL" developed by Bower, Padia, and Glass (1975). The TSX program was then used to assess changes in level and drift of the series. The author recognized that the limited number of data points was a problem, but concluded (p. 35) "...even with this minimal number of data points, the time-series analyses have been illuminative." The author also suggested the use of time-series design to "illuminate" the process of program evaluation as well as its outcomes.

Schnelle and Lee (1974) studied changes in behavior of prison inmates when the policy "prison inmates with behavioral problems would be sent to Brushy Mountain state prison" was implemented. Data were collected seven months prior to the announcement of the new policy. After the intervention, data were collected during 23 months. Statistical analysis using the CORREL and TSX computer programs showed a significant decrease in behavioral problems after the new policy was implemented. The authors caution the readers on the interpretation of
the results. Other plausible explanations are entertained by the authors.

In 1976 Weinstein used a time-series design to study the effects of the classroom physical arrangements upon student behavior. Observation of student behavior was conducted for two weeks before a change in the arrangement was deliberately imposed. Data were collected for two weeks after the intervention. The data included the percentage of time a student was observed in a particular area or the kind of activity in which he/she was involved. The author concluded that significant changes in student behaviors were observed when the classroom arrangement was modified.

Mayer and Lewis (1979) adapted the operant single-subject time-series design described by Glass, Willson, and Gottman (1975), to study student attitudes toward a biology class. One of the major concerns of the study was to determine the reliability and validity of an instrument consisting of five semantic-differential questions. The kind of instructional methods used by the teacher were recorded and correlated with students' mean attitude scores toward the biology class. The authors concluded that the visual inspection of the series was as accurate as were the correlational outcomes.

Summary

The above mentioned studies used time-series to evaluate curriculum or to assess changes in attitudes throughout time. The studies lasted from a few weeks to several months. Only the studies by Schenelle and Lee (1974), and Weinstein (1976) did not require the
subjects to give a direct response to an instrument. The remaining studies involved the use of instruments that the subjects had to answer. None of the studies, however, was concerned with the effect of frequency of testing upon the measurements being taken.

Analysis of Time-Series

Some authors have entertained the problem of analyzing time-series designs with t-tests or ANOVA techniques. One of the assumptions for using those analytic techniques is the independence among observations. In the time-series design, correlation between observations would hamper the use of conventional statistical techniques.

Padia, and Smith (1974) discussed the spurious results that may be obtained when time series designs are approached with t-tests, the authors emphasized earlier findings reported by Padia (1973, 1975) regarding stochastic process "...the more highly autocorrelated the data, the more severe is the departure from the nominal Type I error and power." (Padia and Smith, 1974, p.3)

![Figure 1. Changes in a Time-Series Due to Intervention Effects.](image)
Graph A in Figure 1 represents a time-series in which a downward trend prevailed prior to the intervention. The intervention affected the direction of the series, since there was a definite change in drift. Graph B in Figure 1 represents the opposite. Prior to the intervention the series had a positive slope, which was changed after the intervention. If a t-test is performed on the means of the observations prior to and after the intervention no significant differences will be found. A visual inspection of the figure, however, shows that the intervention (X) had a decisive effect on the trend of the series (change in drift) which is not detected by the t-test. Another case discussed by the author is depicted in Figure 2.

Figure 2. Time-Series Data Showing a Positive Trend.

A t-test on the data plotted on Figure 2 would indicate that there were significant gains after the intervention (X), but in reality the series is simply following its normal pre-established trend.
Hersen and Barlow (1976) also discussed the problems of analyzing time-series with t-tests or analysis of variance techniques. They emphasized the fact that a time-series analytic procedure assesses changes by evaluating level and slope prior to and after intervention.

Nicolich and Weinstein (1976) used t-tests and time-series analytic techniques to analyze Weinstein's (1976) time-series data. The authors concluded that, when there is correlation between observations, a t-test performed on a series of observations had a near 100 percent chance of resulting in a type I error when the 0.05 nominal level was used, whereas the time-series approach had a "...Type I error rate that is not statistically significantly different from 5 percent". (p. 9).

Summary

From these studies it can be concluded that time-series analyses are valuable in those instances in which data are serially correlated. It has been demonstrated that t-tests or ANOVA techniques are unable to detect changes in the trend or level of the series due to an intervention effect. Furthermore, t-test techniques may increase the possibility of committing a Type I error.
CHAPTER III
METHODS AND PROCEDURES

The methods and procedures used in the study are described in this chapter: (1) Research design and description of the criterion and independent variables; (2) subjects participating in the study; (3) curriculum materials used at different stages of the study; (4) item-pools characteristics and instruments; (5) data collection procedures; (6) data analysis; and (7) interviews.

Research Design and Variables

The effects of frequency of testing upon the measurement of achievement on a crustal evolution unit and upon attitudes toward the science class were tested using the multiple-group—single-intervention time-series design. Glass, Willson, and Gottman (1975, p. 20) present this type of design as having a baseline or no treatment period, followed by an intervention or treatment period, and then a follow-up period or time during which the intervention is withdrawn.

Baseline. In a time-series design the baseline helps to assess the level of the series under "normal" conditions. In this study the baseline data provide information regarding the background of the subjects on crustal evolution, and their attitudes toward the science
class. The level of the baseline can be compared to that of the intervention or follow-up periods.

**Intervention.** In this study the intervention is characterized by the use of the crustal evolution unit.

**Follow-up.** This period of time provides insights into the process of retention after the intervention has ceased. In this study the termination of the intervention period does not necessarily mean an instantaneous or complete return to baseline conditions.

Two criterion variables were selected for this study: achievement on a crustal evolution unit, and attitudes toward the science class. Achievement on the crustal evolution unit was assessed with a multiple-choice item pool, whereas attitudes toward the science class were assessed with a semantic-differential item pool. The independent variable selected was frequency of testing. Three testing schedules were studied: (A) every day; (B) about every four days; and (C) about every ten days. Figure 3 shows the three testing schedules.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Base-Line</th>
<th>Intervention</th>
<th>Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0 0 0 0 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0 0 0</td>
</tr>
<tr>
<td>B</td>
<td>0 0 0 0 0</td>
<td>0 0 0 0 0</td>
<td>0 0 0 0 0</td>
</tr>
<tr>
<td>C</td>
<td>0 0 0 0 0</td>
<td>0 0 0 0 0</td>
<td>0 0 0 0 0</td>
</tr>
</tbody>
</table>

Figure 3. Distribution of Testing Schedules.
Subjects

The study was conducted in a suburban junior high school. The four eighth-grade classes of the one earth-science teacher were selected to participate in the study. The school draws students from middle to upper socio-economic status. The four classes ranged from 21 to 23 students. They met each day, two classes in the morning and two in the afternoon. Students within each class were randomly assigned to one of the three testing schedules. Table 1 illustrates the distribution of students by class-period and testing schedules.

<table>
<thead>
<tr>
<th>TESTING SCHEDULES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>7</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

When students were tested, they received two questions: question 1, aimed at assessing achievement on crustal evolution, and question 2, aimed at assessing students' attitudes toward the science class.
The Stanford Achievement Test (form Advanced A) was given to students during September, 1978. The percentile scores on science, reading, and mathematics were gathered from the students' records. IQ scores from the California Test of Mental Maturity given during September 1977, were also obtained. The means and standard deviation for these scores were calculated by testing schedules. Table 2 indicates that students' mean IQ scores are similar regardless of the testing schedule. When science, reading, and mathematics scores are compared, it was found that students in testing schedules B and C slightly outperformed their peers in testing schedule A. The largest difference was found in reading scores between testing schedule A and B (8.4 percentage points).

### TABLE 2

**STUDENTS ACADEMIC CHARACTERISTICS BY TESTING SCHEDULE**

<table>
<thead>
<tr>
<th>Academic Performance</th>
<th>Testing Schedules</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>X^a</td>
</tr>
<tr>
<td>IQ</td>
<td>112.6</td>
</tr>
<tr>
<td>Science</td>
<td>66.3</td>
</tr>
<tr>
<td>Reading</td>
<td>69.2</td>
</tr>
<tr>
<td>Mathematics</td>
<td>68.3</td>
</tr>
</tbody>
</table>

^a = Mean  
^b = Standard deviation
Curriculum Materials

In this section a brief description of the teaching materials presented to the students is introduced. For the baseline and follow-up periods the teacher provided his own units. Special care was taken by the teacher to avoid topics related to crustal evolution during the baseline or follow-up periods.

Baseline. This period of time consisted of ten school days. Students were taught mineralogy and petrology. A great deal of time was devoted to the identification and classification of rocks and minerals. Students were involved in laboratory work and group discussions.

Intervention-Crustal Evolution Unit. A topic rather unfamiliar to the students was selected, therefore allowing for growth in achievement that could be easily detected. Crustal evolution was chosen since the most recent study in this area indicates that little was taught about it in the "standard" earth-science curriculum (Stoever, 1974).

The major goal of the unit was to give to the students an understanding of the earth as a dynamic system in which crust is being produced at the ridges and destroyed in the trenches. To accomplish this three objectives were developed and the unit constructed around them. (Appendix A).

A. Students will be able to describe the major types of evidence that lead scientists to the plate tectonics theory.

B. Students will be able to describe the results of the processes that occur at plate boundaries and the evidence of those processes.
C. Students will be able to explain the mechanism most scientists currently think causes crustal plates to move.

**Crustal Evolution Unit.** The crustal evolution unit consisted of six major topics:

I. Matching the continents together. The students had to match the continents using:
   A. Continental slope borders.
   B. Age, trend, and kind of rocks found in South America, and Africa.
   C. Glacial evidence found in India, Australia, South America, Africa, and Antarctica.

II. Study of the Atlantic sea-floor. This part of the unit required the use of a map depicting the major topographic features of the Atlantic Ocean. It was intended to familiarize the students with features such as: continental slopes, Mid-Atlantic ridge, trenches.

III. Paleomagnetism. This topic introduced the concept of rock magnetic properties and its importance in determining sea floor spreading. The concept of "normal and reverse" polarity was introduced.

IV. Volcanism. Students were presented with volcanism in Iceland. It was intended to relate volcanic activity with crustal evolution. The geologic features found in Iceland were carefully studied.

V. Convection Cells. This topic presented to the student a "possible" mechanism responsible for sea floor spreading.
VI. Earthquakes. A map providing the locations of earthquakes around the world was used to outline the major plates. The students then related earthquake activity to crustal evolution.

**Class-Schedule.** The schedule followed to complete the two-week unit is as follows:

Day 11. (Monday) Students were introduced to the concept of crustal evolution. The objectives of the unit were read by the teacher and different students. The teacher then handed out the activity related to matching the continents. There were group discussions, and then the students answered the questions in the student guides.

Day 12. (Tuesday) The teacher started the class with a slide presentation related to the fitting of the continents together. Then, the students started the activity on matching the continents using rock types, ages, and trends.

Day 13. (Wednesday) The students matched the continents using glacial evidence found in South America, India, Africa, Australia, and Antarctica. This activity was followed by a slide presentation.

Day 14. (Thursday) Students were presented a map of the Atlantic Ocean. They studied the main features of the ocean floor.

Day 15. (Friday) Students continued the study of the topography of the sea floor. Then they answered the questions found in their student guides. The second part of the class-period was devoted to the introduction of paleomagnetism.
Day 16. (Monday) The teacher lectured approximately fifteen minutes on magnetic anomalies, then the students completed the activity. During the last ten minutes of the class-period, slides related to paleomagnetism were shown.

Day 17. (Tuesday) During the first ten minutes of the class-period the students reviewed the slides related to paleomagnetism. Then the topic "Volcanism" was introduced. A filmstrip dealing with volcanism in Iceland was presented.

Day 18. (Wednesday) Students were introduced to the concept of convection cells. They recorded their observations and were involved in group discussions. This was followed by a ten-minute slide presentation.

Day 19. (Thursday) With the aid of a map students observed and delimited world areas characterized by frequent volcanism and earthquakes. The concept of plates was then introduced. This was followed by a slide presentation.

Day 20. (Friday) The movie Continents Adrift was presented as an aid toward reviewing as well as integrating the major concepts related to crustal evolution. The movie was followed by a group discussion.

Follow-up Period. (Monday) Due to weather conditions the school administrators cancelled classes. The follow-up period was characterized by the introduction of an oceanography unit prepared by the teacher. The unit consisted of topics dealing with the importance of the oceans to mankind, the geographic location of the oceans, and the physical characteristics of
the ocean-water. A great deal of time was spent with audiovisual aids. During this period of time special care was taken to avoid topics related to crustal evolution.

Day 21. (Tuesday) The students received the post-test. The semantic differential question and the question from the achievement pool were given followed by the post-test. This procedure was adopted to eliminate the possibility of students reacting to the post-test rather than to the science class.

(Wednesday and Thursday) History fair. The students did not have classes during those days.

Day 22. (Friday) The students read two or three science articles provided by the teacher.

Day 23. (Monday) Review for a test to be given the following day.

Day 24. (Tuesday) Test-period.

Day 25. (Wednesday) The teacher introduced the topic of oceanography. There were slides related to the oceans.

Day 26. (Thursday) There were 30 minutes of slides and filmstrips related to the oceanography unit, then group discussions.

Day 27. (Friday) The movie The Beach a River of Sand was shown to the students followed by questions and group discussions.

Day 28. (Monday) The teacher continued with the oceanography unit.

Day 29. (Tuesday) Oceanography unit. Continuation.

Day 30. (Wednesday) End of the oceanography unit. The last fifteen minutes of the class were devoted to answering the eleven item attitude pool.
Item-Pools and Instruments

Achievement Pool. A pool consisting of 66 multiple-choice items was used to evaluate performance on the crustal evolution unit. The items were developed around the three major objectives of the unit. Objective A was assessed with 22 questions, objective B with 27, and objective C, with 17 questions.

Fifty-four questions had been developed for use in the study by Mayer and Kozlow (1979). They were modified and piloted for this study by Rojas (1978). These items were piloted along with the unit. Two forms, A and B, were designed to evaluate students' performance during the pilot study of the crustal evolution unit. Each form had a core of 20 items. These items were randomly selected to proportionally represent each of the objectives of the unit. The remaining items from the original pool were randomly assigned to one of the two forms, resulting in tests of 37 items each. During the pilot study, 47 eighth graders received form A, whereas 44 received form B. Table 3 summarizes the results obtained when the students' scores were analyzed using the STATPACK ITEMA computer program (The O. S. U. 1977).
TABLE 3

ITEM ANALYSIS OF POOL ITEMS USED DURING THE PILOT STUDY

<table>
<thead>
<tr>
<th></th>
<th>FORM A</th>
<th>FORM B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
<td>47</td>
<td>44</td>
</tr>
<tr>
<td>Mean</td>
<td>23.81</td>
<td>26.32</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>7.76</td>
<td>7.07</td>
</tr>
<tr>
<td>K_r 20</td>
<td>0.89</td>
<td>0.88</td>
</tr>
<tr>
<td>Mean Item Difficulty</td>
<td>0.36</td>
<td>0.29</td>
</tr>
<tr>
<td>Mean Item Discrimination</td>
<td>0.51</td>
<td>0.50</td>
</tr>
<tr>
<td>Number of Items</td>
<td>37</td>
<td>37</td>
</tr>
</tbody>
</table>

Those items whose efficiency, difficulty, and/or discrimination indexes were not considered satisfactory were reworded or changed. University science educators, graduate students in science education, and a high school teacher participated in the revision and modification of the items.

The twelve items added to the original pool were classified according to unit objectives by two faculty members, one graduate student, an earth-science teacher, and the investigator. They have been developed and used in the formative evaluation of modules prepared by the "Crustal Evolution Education Project" (CEEP). Item analysis of those twelve questions using the computer program STATPACK ITEMA (The
O. S. U. 1977) had been performed. Thus, their difficulty levels, and discrimination indexes were known to be acceptable. Nine of the twelve items were unanimously assigned to a given objective. Three of the items, however, could not be assigned to any specific objective since they were related to all three objectives. Each one of the items was then randomly assigned to one of the objectives.

**Instruments-Achievement.** Each of the 31 students in teaching schedule A was randomly assigned a different question every day for 30 days. Randomization without replacement was conducted to assure that each student received a different question every day. The questions assigned had to proportionally represent each of the three objectives of the unit. Thus objective A had ten questions every day, objective B thirteen questions, and objective C was represented by nine.

A post-test was given to all the students on day 21. Two forms were designed, A and B. Each form had a core of the same twelve items randomly assigned to each form. Form A was randomly assigned to the second and sixth class-periods, and form B to the third and seventh.

**Attitude-Pool.** Attitudes toward "today's" science class were determined using items drawn from a pool developed by Farnsworth (1978) to determine the relationship between student attitude toward earth-science class and events occurring during the class-period. The pool consisted of eleven items. Each item had two bipolar adjectives with five possible locations between them. The adjectives represented four dimensions: activity, evaluation, potency, and understanding. The reliability of the instrument, determined by Farnsworth, varied from 0.78 to 0.86.
**Attitude Instruments.** The size of the attitude-pool was doubled by reversing the adjective pairs, hence the initial eleven pairs increased to twenty-two. These items were then randomly assigned to the 66 multiple-choice items, thus each pair was used three times. The item pools can be found in Appendix B. In order to determine the Hoyt reliability of the attitude pool, it was decided to give the whole pool to all the students. This was accomplished the last day of the follow-up period.

**Data Collection Procedures**

The following procedures were used to collect students' responses to the daily achievement and attitude questions: A folder was provided for each of the participants and was marked with the student's name and identification number. An easily coded answer sheet was stapled to each folder.

During the six weeks of the study, three minutes before the end of the period each student received his/her folder which contained either two questions and a paragraph, or only a paragraph. The paragraph related to the material covered in the class, and most of the time consisted of excerpts from earth-science books or science magazines. An example of an answer sheet and some of the paragraphs can be found in Appendix C.

The first item on the questionnaire was related to achievement, and the second question was the attitude item. The students had to select a letter (A, B, C, D, or E) for each question and write it on their answer sheet. Students on testing schedule A received the two
questions and the paragraph every day for 30 days. When students belonging to testing schedules B or C received the two questions, they were given the same set of questions asked of their peers in testing schedule A. Hence, achievement and attitudes could be compared between testing schedules. On those days in which students on testing schedules B or C were not tested, they received only the paragraph.

Every day at the end of the school day, the investigator collected the students' folders and replaced the items and paragraphs with the appropriate ones for the following day. A record was kept of absenteeism.

To familiarize the students with the procedure to be used so that they would regard it as a part of the regular class routine, the week prior to the initiation of the study, the teacher informed his students that for the next seven weeks, three minutes before the end of the period, each one of them was going to receive a folder marked with their names, identification number, and containing two questions and a paragraph. During this week, however, all the students received only the paragraph.

The first day of the study the students were told by the teacher and the investigator the purpose of the study. Basically it was said: "...we are interested in learning what you think about the science class and about your performance throughout time. We are trying to find better ways to teach science so that you will enjoy the science class more..." Students were also told to be as "honest" as they could while answering the questions. Finally the students were told that their performance would not affect their science grades assigned by the teacher.
Data Analysis

Post-test Analysis. The reliability of the post-test (forms A and B) was determined using the STATPACK ITEMA computer program (The O. S. U. 1977). Mean item difficulty and mean item discrimination indexes were also obtained. The same program was also run on the core items alone.

Initially twelve items comprised the item core. However a typographical error on form B of the post-test prevented one of the items from being used. The mean item difficulty of the core items on form A was 36.40, and on form B, 32.00, indicating a possible difference among the two groups of students in their understanding of crustal evolution. To equate the difficulty level of all the items, the difference of 4.40 between the two forms was added to the difficulty of each item that appeared on form B. Once the difficulties had been adjusted, a mean difficulty level per day was also calculated and plotted.

Daily Instruments. Daily mean achievement scores for each testing schedule were calculated and plotted. In order to determine if frequency of testing had any effect upon the measurement of achievement, mean achievement scores on days 1, 21, and 30 were analyzed using the BMD02V analysis of variance computer program (Dixon, 1970).

Significant differences between the post-test mean achievement scores by testing schedules and by class periods were assessed with a 3 by 4 analysis of variance. The STATPACK BALANOVA computer program (The O. S. U., 1977) was used.
Attitude Pool Analysis. The whole attitude pool given on day 30 was analyzed using the FORTAP (Gltap and Rave) program (Bauman 1973). Separate analyses were conducted to determine the Hoyt reliability of the instrument with each testing schedule.

Daily mean attitudes toward "today's" science class were also calculated and plotted. In order to assess the statistical significance of differences between attitude scores on day 30, a 3 by 4 analysis of variance was conducted. Similar analysis were conducted to determine mean attitude differences between testing schedules on days 1 and 21.

Time-Series Analyses. Data collected on students assigned to testing schedule A were submitted to a time-series analysis. The purpose of the time-series is to detect changes in level and/or drift of the series due to an intervention effect. Two computer programs (CORREL and TSX) developed by Bower, Padia, and Glass (1975) were used to analyze the achievement as well as the attitude series.

In order to graphically and mathematically show the pattern of change in: achievement and attitudes during baseline, intervention, and follow-up for testing schedule A, separate regression equations were calculated using the STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES program REGRESSION (Nie et al., 1975). These equations as well as the graphs of the best fitting lines help to understand the achievement or attitude trends of the series throughout time. They also provide a more accurate "picture" of the achievement and attitude scores throughout the study.

A Pearson Product Moment Correlation Coefficient was selected to assess if performance on a given day during the intervention period had
been influenced by the fact that the content of the achievement question had been covered that day or before. To accomplish this task, the following coding was used: one (1) defined a question that had been covered in class, whereas a zero (0) represented a question asked but not yet covered. This correlation was done using the STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES program PEARSON CORR (Nie et al., 1975).

Interviews

In order to assess the validity of the data collection procedures, a series of interviews were conducted. Seven males and five females were randomly selected to be interviewed by the investigator. Each of the three testing schedules was represented by four students. The day after the study was completed, the interview schedule (Appendix D) was used. The schedule had questions assessing students' attitudes toward the science class, toward the crustal evolution unit, and toward the student's testing schedule. Each interview lasted about five minutes.
CHAPTER IV

RESULTS OF THE STUDY

The results of the study are described in three major sections. The first section focuses on the reliability measures of the post-tests, and on item difficulties of the achievement items. Section two concentrates on the reliability measures of the attitude pool given on day 30. Section three is devoted to the results of the analyses conducted to test each one of the hypotheses.

Post-Test Analyses

Since differences in item characteristics selected on a given day for the achievement instrument could lead to erroneous conclusions, it was necessary to develop a system which could provide estimates of the difficulty level of each of the items forming the achievement pool. It was decided to give a post-test to all the students. Day 21 was chosen as the best "target day", since it represented the first day after the intervention had been withdrawn, therefore all of the items had been covered in the classroom.

Based upon previous experiences with the item pool, it was considered inappropriate to administer the whole achievement pool to all the students. Instead, two forms (A and B) having twelve items in
common were randomly assigned to each period. Form A was assigned to
the second and third periods, whereas form B was assigned to the sixth
and seventh periods. The twelve common items could be used as control
for possible differences in students' understanding of crustal evolution.

The characteristics of the post-tests were determined by submitting
the post-test scores to analysis by the STATPACK ITEMA computer program
(The O. S. U., 1977). Forms A and B were separately analyzed and the
results are presented in Table 4. Each form had a reliability of 0.89
($K_{r20}$) indicating the consistency of both forms.

| TABLE 4 |
| POST-TEST ITEM ANALYSIS |
| DAY 21 |

<table>
<thead>
<tr>
<th></th>
<th>Form A</th>
<th>Form B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Mean</td>
<td>25.61</td>
<td>26.48</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>7.58</td>
<td>7.39</td>
</tr>
<tr>
<td>$K_{r20}$</td>
<td>0.89</td>
<td>0.89</td>
</tr>
<tr>
<td>Mean Item Difficulty</td>
<td>0.34</td>
<td>0.30</td>
</tr>
<tr>
<td>Mean Item Discrimination</td>
<td>0.48</td>
<td>0.48</td>
</tr>
<tr>
<td>Number of Items</td>
<td>38</td>
<td>38</td>
</tr>
</tbody>
</table>

Differences between students assigned to forms A or B were assessed
by analyzing the core items alone. Table 5 indicates that there is a
mean item difficulty difference of 0.04 (four percent) which can be
regarded as insignificant.
### TABLE 5
CORE ITEMS ANALYSIS FROM POST-TEST DAY 21

<table>
<thead>
<tr>
<th></th>
<th>Form A</th>
<th>Form B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
<td>44</td>
<td>44</td>
</tr>
<tr>
<td>Mean</td>
<td>7.00</td>
<td>7.48</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>2.36</td>
<td>2.33</td>
</tr>
<tr>
<td>$K_{20}$</td>
<td>0.64</td>
<td>0.68</td>
</tr>
<tr>
<td>Mean Item Difficulty</td>
<td>0.36</td>
<td>0.32</td>
</tr>
<tr>
<td>Mean Item Discrimination</td>
<td>0.57</td>
<td>0.51</td>
</tr>
<tr>
<td>Number of Items</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

In spite of the small differences in mean item difficulty levels, it was decided to add four percentage points to the difficulty level of each item on form B. Table 6 shows the adjusted difficulty level of each item forming the pool.

An examination of Table 6 indicates that the pool consisted of items with a wide range of difficulty levels. The lowest difficulty level was 6.7 whereas the highest difficulty level was found to be 65.9.
<table>
<thead>
<tr>
<th>Item</th>
<th>Diff *</th>
<th>Item</th>
<th>Diff *</th>
<th>Item</th>
<th>Diff *</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>31.3</td>
<td>23</td>
<td>31.7</td>
<td>45</td>
<td>40.9</td>
</tr>
<tr>
<td>02</td>
<td>51.1</td>
<td>24</td>
<td>47.7</td>
<td>46</td>
<td>56.7</td>
</tr>
<tr>
<td>03</td>
<td>22.7</td>
<td>25</td>
<td>13.6</td>
<td>47</td>
<td>39.7</td>
</tr>
<tr>
<td>04</td>
<td>6.7</td>
<td>26</td>
<td>54.4</td>
<td>48</td>
<td>31.8</td>
</tr>
<tr>
<td>05</td>
<td>34.1</td>
<td>27</td>
<td>47.7</td>
<td>49</td>
<td>18.2</td>
</tr>
<tr>
<td>06</td>
<td>52.2</td>
<td>28</td>
<td>31.8</td>
<td>50</td>
<td>24.9</td>
</tr>
<tr>
<td>07</td>
<td>27.1</td>
<td>29</td>
<td>65.9</td>
<td>51</td>
<td>36.2</td>
</tr>
<tr>
<td>08</td>
<td>15.9</td>
<td>30</td>
<td>29.5</td>
<td>52</td>
<td>27.3</td>
</tr>
<tr>
<td>09</td>
<td>13.5</td>
<td>31</td>
<td>27.1</td>
<td>53</td>
<td>27.1</td>
</tr>
<tr>
<td>10</td>
<td>25.0</td>
<td>32</td>
<td>45.2</td>
<td>54</td>
<td>54.4</td>
</tr>
<tr>
<td>11</td>
<td>22.6</td>
<td>33</td>
<td>27.1</td>
<td>55</td>
<td>33.9</td>
</tr>
<tr>
<td>12</td>
<td>18.2</td>
<td>34</td>
<td>45.3</td>
<td>56</td>
<td>24.9</td>
</tr>
<tr>
<td>13</td>
<td>29.5</td>
<td>35</td>
<td>31.7</td>
<td>57</td>
<td>38.6</td>
</tr>
<tr>
<td>14</td>
<td>18.2</td>
<td>36</td>
<td>54.4</td>
<td>58</td>
<td>15.9</td>
</tr>
<tr>
<td>15</td>
<td>24.9</td>
<td>37</td>
<td>38.6</td>
<td>59</td>
<td>64.7</td>
</tr>
<tr>
<td>16</td>
<td>25.0</td>
<td>38</td>
<td>15.9</td>
<td>60</td>
<td>54.5</td>
</tr>
<tr>
<td>17</td>
<td>34.1</td>
<td>39</td>
<td>31.7</td>
<td>61</td>
<td>52.3</td>
</tr>
<tr>
<td>18</td>
<td>20.3</td>
<td>40</td>
<td>75.0</td>
<td>62</td>
<td>47.7</td>
</tr>
<tr>
<td>19</td>
<td>49.9</td>
<td>41</td>
<td>27.1</td>
<td>63</td>
<td>38.5</td>
</tr>
<tr>
<td>20</td>
<td>13.6</td>
<td>42</td>
<td>25.0</td>
<td>64</td>
<td>40.8</td>
</tr>
<tr>
<td>21</td>
<td>47.6</td>
<td>43</td>
<td>12.4</td>
<td>65</td>
<td>47.7</td>
</tr>
<tr>
<td>22</td>
<td>19.2</td>
<td>44</td>
<td>31.7</td>
<td>66</td>
<td>25.0</td>
</tr>
</tbody>
</table>

*Percentage of students missing the item.*
To determine if the item difficulty had any systematic effect on achievement, it was decided to calculate and plot the daily mean item difficulty. As shown in Table 7 the daily mean item difficulty levels ranged from 31.2 to 38.8.

**TABLE 7**

**DAILY ITEM DIFFICULTY USING POST-TEST DAY 21**

<table>
<thead>
<tr>
<th>Day</th>
<th>MID*</th>
<th>Day</th>
<th>MID*</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>33.4</td>
<td>16</td>
<td>36.2</td>
</tr>
<tr>
<td>02</td>
<td>35.6</td>
<td>17</td>
<td>33.5</td>
</tr>
<tr>
<td>03</td>
<td>33.2</td>
<td>18</td>
<td>31.8</td>
</tr>
<tr>
<td>04</td>
<td>34.2</td>
<td>19</td>
<td>35.6</td>
</tr>
<tr>
<td>05</td>
<td>37.8</td>
<td>20</td>
<td>31.2</td>
</tr>
<tr>
<td>06</td>
<td>34.6</td>
<td>21</td>
<td>32.3</td>
</tr>
<tr>
<td>07</td>
<td>37.7</td>
<td>22</td>
<td>38.8</td>
</tr>
<tr>
<td>08</td>
<td>34.8</td>
<td>23</td>
<td>33.1</td>
</tr>
<tr>
<td>09</td>
<td>34.6</td>
<td>24</td>
<td>34.3</td>
</tr>
<tr>
<td>10</td>
<td>33.6</td>
<td>25</td>
<td>33.8</td>
</tr>
<tr>
<td>11</td>
<td>35.2</td>
<td>26</td>
<td>33.7</td>
</tr>
<tr>
<td>12</td>
<td>36.9</td>
<td>27</td>
<td>34.4</td>
</tr>
<tr>
<td>13</td>
<td>33.8</td>
<td>28</td>
<td>36.4</td>
</tr>
<tr>
<td>14</td>
<td>37.2</td>
<td>29</td>
<td>33.5</td>
</tr>
<tr>
<td>15</td>
<td>33.4</td>
<td>30</td>
<td>35.8</td>
</tr>
</tbody>
</table>

* Mean Item Difficulty
The plot of mean item difficulties per day (Figure 4) indicates that throughout the study there was not a drastic change of the mean item-difficulty levels.

It would be accurate to state that daily mean achievement scores are little affected by the difficulty level of the questions on any given day. This plot can also be interpreted as the result of an effective randomization procedure in which items were evenly distributed every day.

**Attitude-Pool Analyses**

The reliability of the whole attitude instrument given on day 30 was assessed using the FORTAP (Gitap and Rave) computer program (Bauman, 1973). Table 8 presents the Hoyt reliability. A copy of the item analysis output is presented in Appendix E.
When the Rave routine was used, the internal consistency of the instrument increased. This program uses "...a priori set of item response weights assigned by the investigator to initiate an iterative process which converges to a weighting scheme which maximizes the internal consistency of the instrument" (Bauman, 1973, p. 8). The "new" Hoyt reliability calculated with the optimum weights was 0.89. It can be concluded that the reliability of the attitude pool with the weights defined by several members of the Science and Mathematics Education Faculty of The Ohio State University, five graduate students in science education, and several junior high school teachers, does not differ markedly from that obtained by the Rave program.

Even though the instrument showed an "acceptable" reliability, it was decided to determine the consistency of the instrument with each testing schedule (A, B, and C). Table 9 indicates that the semantic differential instrument was consistent (reliable) with the students in
any of the three testing schedules.

TABLE 9
HOYT RELIABILITY OF THE ATTITUDE INSTRUMENT
BY TESTING SCHEDULE

<table>
<thead>
<tr>
<th>TESTING SCHEDULES</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability</td>
<td>0.87</td>
<td>0.83</td>
<td>0.88</td>
</tr>
<tr>
<td>Subjects</td>
<td>27</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>Items</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
</tbody>
</table>

Testing Hypotheses

The results of the analyses conducted to test the hypotheses will be presented in this section.

Hypothesis 1. Students' mean performance on the objectives of the crustal evolution unit will be similar regardless of the testing schedule.

In order to test this hypothesis the mean performance of students on each testing schedule was calculated. The results are presented in Table 10. A plot was then constructed with "day" on the abscissa and mean percentage of correct responses on the ordinate. Figure 5 depicts the pattern followed by each testing schedule.
<table>
<thead>
<tr>
<th>Day</th>
<th>GROUP A</th>
<th>GROUP B</th>
<th>GROUP C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean N</td>
<td>Mean N</td>
<td>Mean N</td>
</tr>
<tr>
<td>01</td>
<td>34.0 29</td>
<td>46.0 26</td>
<td>44.0 25</td>
</tr>
<tr>
<td>02</td>
<td>43.0 28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>03</td>
<td>37.0 27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>04</td>
<td>46.0 28</td>
<td>41.0 27</td>
<td></td>
</tr>
<tr>
<td>05</td>
<td>38.0 21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>06</td>
<td>45.0 29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>07</td>
<td>43.0 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>08</td>
<td>47.0 30</td>
<td>51.0 25</td>
<td></td>
</tr>
<tr>
<td>09</td>
<td>43.0 28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>41.0 27</td>
<td></td>
<td>46.0 24</td>
</tr>
<tr>
<td>11</td>
<td>52.0 29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>41.0 29</td>
<td>42.0 26</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>42.0 31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>57.0 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>33.0 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>53.0 30</td>
<td>58.0 26</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>41.0 27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>65.0 31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>55.0 29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>52.0 21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>64.0 31</td>
<td>56.0 27</td>
<td>85.2 27</td>
</tr>
<tr>
<td>22</td>
<td>61.0 31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>55.0 29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>47.0 30</td>
<td>54.0 24</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>74.0 31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>67.0 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>47.0 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>57.0 21</td>
<td>57.0 21</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>55.0 29</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>64.0 28</td>
<td>68.0 22</td>
<td>77.0 26</td>
</tr>
</tbody>
</table>

* N of cases.
Figure 5. Achievement Throughout Time.
An examination of Figure 5 seems to indicate that there are differences in achievement scores among students on the three testing schedules. A look at the mean achievement scores for testing schedules A and B indicates that of the nine common days at which data were collected for both of them, six times students on testing schedule B slightly outperformed students on testing schedule A. The largest difference occurred on day 21.

Students on testing schedule C outperformed those on A every time they were tested. The largest difference occurred on day 21.

Students on testing schedules B and C had only three common testing days. Days 1, 21 and 30. Students on testing schedule C outperformed those on testing schedule B on the last two days. The largest difference occurred on day 21 (29.0 percentage points).

Analysis of Variance. A visual inspection of Figure 5 and the comparison between mean achievement scores of the three testing schedules seem to favor testing schedule C over B and A on performance on the crustal evolution unit, leading to the possible conclusion that testing schedules indeed have an effect upon achievement. The statistical significance of those differences was assessed using analyses of variance on mean achievement scores on days 1, 21, and 30.

Day 21: Students' achievement scores on the one-item instrument given on day 21 were analyzed using a one-factor repeated measurement design. The BMD02V computer program (Dixon, 1970) was used to conduct the analysis. Since each cell comprised one subject, those questions not answered on day 21 had to be deleted from the three testing schedules. The results are presented in Table 11.
Table 11 indicates that there is a significant difference between the mean achievement scores of the three testing schedules. A follow-up procedure was then used to assess the differences. A post-hoc analysis using Tukey's HSD technique yielded statistically significant differences between the mean scores for testing schedules B and C. No significant differences were found on the other pairwise comparisons.

The critical value required to achieve significance ($R$) at the .05 level was 30.0 (df. 3, 46). Table 12 shows the mean scores and standard deviations of the three testing schedules.

To determine if statistically significant differences in mean performance existed at the beginning of the study, a one-factor repeated measurement analysis was conducted on day 1. Table 13 shows the results of the analysis. As expected, no statistically significant differences were found between the mean achievement scores of the three testing schedules. A difference of approximately 28.0 percentage points between testing schedules would have been required to achieve significance at
TABLE 12
MEANS AND STANDARD DEVIATIONS OF ACHIEVEMENT SCORES ON DAY 21
BY TESTING SCHEDULES

<table>
<thead>
<tr>
<th>Testing Group</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>62.0</td>
<td>48.0</td>
</tr>
<tr>
<td>B</td>
<td>54.0</td>
<td>50.0</td>
</tr>
<tr>
<td>C</td>
<td>87.0</td>
<td>36.0</td>
</tr>
</tbody>
</table>

TABLE 13
ANALYSIS OF VARIANCE OF ACHIEVEMENT SCORES ON DAY 1
BY TESTING SCHEDULES AND BY ITEMS

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing Schedules (A)</td>
<td>2</td>
<td>0.88</td>
<td>0.44</td>
<td>3.1</td>
</tr>
<tr>
<td>Items (B)</td>
<td>18</td>
<td>7.50</td>
<td>0.42</td>
<td>3.0*</td>
</tr>
<tr>
<td>Residual</td>
<td>36</td>
<td>5.12</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>56</td>
<td>13.50</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.01
the 0.05 level with a statistical power of 0.85 (Winer 1962).

An analysis of achievement scores on day 30 was also performed using a one-factor repeated measurement procedure. The results presented in Table 14 indicate that there were no significant differences in mean achievement scores among the three testing schedules. The critical value required to achieve significance at the 0.05 level is 3.28. A difference of approximately 31.0 percentage points between testing schedules would have been required to achieve significance at the 0.05 level with a statistical power of 0.85.

TABLE 14
ANALYSIS OF VARIANCE OF ACHIEVEMENT SCORES ON DAY 30
BY TESTING SCHEDULES AND BY ITEMS

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing schedules (A)</td>
<td>2</td>
<td>0.33</td>
<td>0.17</td>
<td>1.0</td>
</tr>
<tr>
<td>Items (B)</td>
<td>17</td>
<td>6.83</td>
<td>0.40</td>
<td>2.3*</td>
</tr>
<tr>
<td>Residual</td>
<td>34</td>
<td>5.67</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>53</td>
<td>12.83</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p ≤ 0.05

The results of the analyses of variance conducted on mean achievement scores on the one-item instrument given on days 1, 21, and 30 indicate that only testing schedule C significantly outperformed testing schedule B on day 21. The remaining differences were not found to be statistically significant.
Since the number of students taking the tests on days 1, 21, and 30 varied, it could be argued that the achievement scores obtained were the result of different populations being tested. To eliminate this concern it was decided to analyze the scores of only those students who were present for every one of the three days. This resulted in ten students from each testing schedule whose scores were suitable for analysis. Table 15 indicates that students on testing schedule C outperformed their peers on testing schedule A every time common testing was present. Similarly, students on testing schedule B outperformed those on testing schedule A on each of the three common testing days.

TABLE 15
MEAN ACHIEVEMENT SCORES BY DAY AND BY TESTING SCHEDULE *

<table>
<thead>
<tr>
<th>Frequency of Testing</th>
<th>Day 1</th>
<th>Day 21</th>
<th>Day 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10.0</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>B</td>
<td>40.0</td>
<td>60.0</td>
<td>70.0</td>
</tr>
<tr>
<td>C</td>
<td>40.0</td>
<td>80.0</td>
<td>70.0</td>
</tr>
</tbody>
</table>

*Ten subjects by testing schedule.

The analysis of variance on mean achievement scores on days 1, 21, and 30 indicate that none of the mean achievement scores presented in Table 15 were significantly different from each other. The mean
achievement scores shown in the above table do not agree with the results obtained when different populations were analyzed (See Figure 5). Table 15 indicates that when the same students are compared the achievement pattern is always the same. That is, students on testing schedule C outperformed their peers on testing schedule A, and students on testing schedule B outperformed those on testing schedule A. Testing schedule C outperformed B on day 21, the remaining two days show exactly the same mean achievement scores for both groups. These relationships suggest that frequency of testing did not affect achievement on the crustal evolution unit. Even if significant differences had been found on mean achievement scores on days 1, 21, or 30 these may have merely indicated that achievement scores were different at the beginning of the study and remained different on days 21, and 30, the difference being not affected by frequency of testing. The replication of the pattern on days 21 and 30 would support the claim of no effects on achievement scores due to frequency of testing.

Post-Test Analysis. An additional way to test hypothesis 1 was to analyze the mean achievement scores obtained by the students when the post-test was given. Table 16 presents the mean achievement scores by testing schedule and by class-period.

Post-test scores were submitted to a 3 X 4 analysis of variance using the STATPACK BALANOVA program (The O. S. U., 1977). Even though this study focused on the effects of frequency of testing upon measurement of achievement, class-periods were introduced in the design as a blocking variable so that power would be enhanced. A difference of approximately 6.5 units between testing schedules would have been
### TABLE 16
MEANS OF POST-TEST SCORES BY TESTING SCHEDULES AND BY CLASS-PERIODS

<table>
<thead>
<tr>
<th>Testing Schedules</th>
<th>Period.</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second</td>
<td>24.5</td>
<td>23.5</td>
<td>26.0</td>
<td></td>
<td>24.7</td>
</tr>
<tr>
<td>Third</td>
<td>24.5</td>
<td>30.1</td>
<td>27.8</td>
<td></td>
<td>27.5</td>
</tr>
<tr>
<td>Sixth</td>
<td>30.0</td>
<td>23.1</td>
<td>27.0</td>
<td></td>
<td>26.7</td>
</tr>
<tr>
<td>Seventh</td>
<td>23.8</td>
<td>26.4</td>
<td>26.8</td>
<td></td>
<td>25.7</td>
</tr>
<tr>
<td>Total</td>
<td>25.7</td>
<td>25.8</td>
<td>26.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 17
ANALYSIS OF VARIANCE OF POST-TEST SCORES BY TESTING SCHEDULES AND BY CLASS-PERIODS

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class-Periods (A)</td>
<td>3</td>
<td>99.99</td>
<td>33.33</td>
<td>0.56</td>
</tr>
<tr>
<td>Testing Schedules (B)</td>
<td>2</td>
<td>27.46</td>
<td>13.73</td>
<td>0.23</td>
</tr>
<tr>
<td>A x B</td>
<td>6</td>
<td>327.40</td>
<td>54.57</td>
<td>0.92</td>
</tr>
<tr>
<td>Residual</td>
<td>67</td>
<td>4490.64</td>
<td>59.10</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>78</td>
<td>4945.49</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
necessary to achieve significance at the 0.05 level with a statistical power of 0.85.

Hypothesis 1, Conclusions. The hypothesis that "Students' mean performance on the objectives of the crustal evolution unit will be similar regardless of the testing schedule" was tested in three ways. (1) Analyses of variance on mean achievement scores on days 1, 21, and 30 indicate that on day 21 students on testing schedule C performed significantly better than their peers on testing schedule B. The remaining differences were not significant. (2) Analyses of variance on mean achievement scores of only those students who were present all three days indicate that no significant differences were present between testing schedules on any of the three testing days. The pattern followed by the three testing schedules on days 1, 21, and 30 seems to indicate that frequency of testing did not change the differences present at the beginning of the study. Students in testing schedule C outperformed their peers on testing schedule B. Similarly, students in testing schedule B outperformed those on testing schedule A on the three common testing days. Students on testing schedule B were outperformed by C only on day 21, the remaining two days indicate that both testing schedules obtained the same mean scores. (3) The analysis of variance conducted on post-test scores obtained on day 21 support the claim that frequency of testing did not affect achievement on the crustal evolution unit.

Hypothesis 2. Students' mean attitudes toward today's science class will be similar regardless of the testing schedule.
In order to test this hypothesis, mean attitude scores were calculated for students in each testing schedule and are included in Table 18.

TABLE 18
DAILY MEAN ATTITUDE SCORES

<table>
<thead>
<tr>
<th>Day</th>
<th>GROUP A</th>
<th></th>
<th>GROUP B</th>
<th></th>
<th>GROUP C</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>N</td>
<td>Mean</td>
<td>N</td>
<td>Mean</td>
<td>N</td>
</tr>
<tr>
<td>01</td>
<td>2.9</td>
<td>29</td>
<td>2.8</td>
<td>26</td>
<td>3.2</td>
<td>25</td>
</tr>
<tr>
<td>02</td>
<td>2.8</td>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>03</td>
<td>2.4</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>04</td>
<td>2.7</td>
<td>28</td>
<td>3.0</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>05</td>
<td>3.2</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>06</td>
<td>2.9</td>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>07</td>
<td>3.1</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>08</td>
<td>2.9</td>
<td>30</td>
<td>2.9</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>09</td>
<td>3.1</td>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3.2</td>
<td>27</td>
<td></td>
<td></td>
<td>2.8</td>
<td>23</td>
</tr>
<tr>
<td>11</td>
<td>2.7</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>12</td>
<td>3.1</td>
<td>29</td>
<td>2.7</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>3.2</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>2.9</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>2.8</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>3.0</td>
<td>30</td>
<td>2.6</td>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>3.1</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>3.4</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>19</td>
<td>3.2</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>20</td>
<td>3.1</td>
<td>21</td>
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<td></td>
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<tr>
<td>21</td>
<td>3.0</td>
<td>31</td>
<td>2.8</td>
<td>27</td>
<td>2.6</td>
<td>26</td>
</tr>
<tr>
<td>22</td>
<td>2.9</td>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>3.2</td>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>3.0</td>
<td>29</td>
<td>3.5</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>2.8</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>3.2</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>3.7</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>2.9</td>
<td>21</td>
<td>3.0</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>3.7</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>3.0*</td>
<td>27</td>
<td>2.8*</td>
<td>25</td>
<td>3.0*</td>
<td>25</td>
</tr>
</tbody>
</table>

* The mean attitude score for the whole instrument was divided by eleven (number of questions).
The mean attitude scores were then plotted with "day" on the abscissa and mean attitude scores on the ordinate. Figure 6 shows the pattern followed by each testing schedule. A visual inspection of Figure 6 seems to indicate that, although changes in attitudes have occurred, there is no definite trend followed by any of the testing schedules.

Of the nine days in which students on testing schedule A and B answered the instrument, students on testing schedule A showed more positive mean attitude scores toward the science class than did those on testing schedule B for five of the nine days. On three days students on testing schedule B outscored students on testing schedule A, and once their scores were the same.

In regard to students on testing schedules B and C, four days were common to both groups. Students on testing schedule B outscored students on testing schedule C only once. The remaining three days showed students' attitudes on testing schedule C slightly more positive than those of students on testing schedule B.

Students on testing schedule A outscored those on testing schedule C twice, testing schedule C outscored A once, and once they had the same attitude scores.

Analysis of Variance. An examination of Figure 6 seems to indicate that even though mean attitude scores differ, there does not seem to be a clear "superiority" of any of the three testing schedules. In order to assess the statistical significance of the attitude differences between testing schedules, analysis of variance was used.
Figure 6. Mean Attitudes Toward Today's Science Class.
Day 30: A 3 X 4 analysis of variance using the STATPACK BALANOVA program (The O. S. U., 1977) was conducted on students' attitude scores on day 30. As with achievement scores, the design layout allowed for the use of class-periods as the blocking variable. The results are presented in Table 19. The analysis of variance summary table indicates that there were no significant differences between mean attitude scores per testing schedule. A critical value of 3.14 is required to achieve significance at the 0.05 level. Regarding the effect of the blocking variable (class-period), it can be observed that no significant differences were detected between class-periods.

### TABLE 19

**ANALYSIS OF VARIANCE OF ATTITUDE SCORES ON DAY 30 BY TESTING SCHEDULES AND BY CLASS-PERIODS**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class-Periods (A)</td>
<td>3</td>
<td>286.93</td>
<td>95.64</td>
<td>1.19</td>
</tr>
<tr>
<td>Testing Schedules (B)</td>
<td>2</td>
<td>76.18</td>
<td>38.09</td>
<td>0.47</td>
</tr>
<tr>
<td>A x B</td>
<td>6</td>
<td>424.86</td>
<td>70.81</td>
<td>0.88</td>
</tr>
<tr>
<td>Residual</td>
<td>67</td>
<td>5389.86</td>
<td>80.44</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>78</td>
<td>6177.83</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To determine if students' attitude scores were similar at the beginning of the study, it was considered necessary to assess the attitude scores obtained on day 1. A one-factor repeated measurement design was used. The analysis of variance was conducted using the BMD02V computer program (Dixon, 1979). The results are presented in Table 20.
The results presented in Table 20 indicate that no significant differences were present between mean attitude scores by testing schedules. A critical value of 3.26 is required to achieve significance.

A similar analysis was conducted on day 21. Table 21 indicates that no significant differences were found between mean attitude scores per testing schedule.

### Table 20

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing Schedules (A)</td>
<td>2</td>
<td>1.51</td>
<td>0.75</td>
<td>0.52</td>
</tr>
<tr>
<td>Items (B)</td>
<td>18</td>
<td>35.89</td>
<td>1.99</td>
<td>1.40</td>
</tr>
<tr>
<td>Residual</td>
<td>36</td>
<td>51.16</td>
<td>1.42</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>56</td>
<td>88.56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 21

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing Schedules (A)</td>
<td>2</td>
<td>0.38</td>
<td>0.19</td>
<td>0.06</td>
</tr>
<tr>
<td>Items (B)</td>
<td>22</td>
<td>57.90</td>
<td>2.63</td>
<td>0.86</td>
</tr>
<tr>
<td>Residual</td>
<td>44</td>
<td>133.62</td>
<td>3.04</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>68</td>
<td>191.90</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Hypothesis 2. Conclusions. The hypothesis that "Students' mean attitudes toward today's science class will be similar regardless of the testing schedule" was accepted. The results obtained when hypothesis two was tested indicate that, throughout the study, students' attitudes toward today's science class were not affected by frequency of testing. The results of the analyses of variance conducted on attitude scores on day 1, 21, and 30 indicate that the mean attitude scores obtained by students on each testing schedule were not significantly different from each other.

Hypothesis 3. There will be a significant change in achievement during the intervention period followed by a down trend in achievement during the follow-up period.

In order to test this hypothesis, scores on testing schedule A were analyzed. Insufficient data points in testing schedules B and C did not permit the use of the time-series analysis computer programs. The analysis of students' data for testing schedule A was conducted using the computer programs CORREL and TSX developed by Bower, Padia, and Glass (1975).

The CORREL (correlogram) program provides the user with autocorrelation coefficients for data comprising baseline, intervention, and follow-up. In this study three correlograms were requested. Tables 22, 23, and 24 summarize the results obtained when data were analyzed at different lags (one to five).
### TABLE 22
CORRELOGRAM FOR ACHIEVEMENT SCORES*
BASELINE DATA

<table>
<thead>
<tr>
<th>Lag</th>
<th>R</th>
<th>SE</th>
<th>Partial R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.29</td>
<td>0.31</td>
<td>-0.29</td>
</tr>
<tr>
<td>2</td>
<td>0.53</td>
<td>0.34</td>
<td>0.48</td>
</tr>
<tr>
<td>3</td>
<td>-0.40</td>
<td>0.42</td>
<td>-0.22</td>
</tr>
<tr>
<td>4</td>
<td>0.27</td>
<td>0.46</td>
<td>-0.01</td>
</tr>
<tr>
<td>5</td>
<td>-0.20</td>
<td>0.47</td>
<td>-0.31</td>
</tr>
</tbody>
</table>

R = Autocorrelation coefficient  
SE = Standard error  
* Correlogram without differencing (d=0).

### TABLE 23
CORRELOGRAM FOR ACHIEVEMENT SCORES*
INTERVENTION DATA

<table>
<thead>
<tr>
<th>Lag</th>
<th>R</th>
<th>SE</th>
<th>Partial R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.32</td>
<td>0.31</td>
<td>-0.32</td>
</tr>
<tr>
<td>2</td>
<td>0.30</td>
<td>0.34</td>
<td>0.23</td>
</tr>
<tr>
<td>3</td>
<td>-0.24</td>
<td>0.37</td>
<td>-0.09</td>
</tr>
<tr>
<td>4</td>
<td>0.03</td>
<td>0.38</td>
<td>-0.07</td>
</tr>
<tr>
<td>5</td>
<td>-0.04</td>
<td>0.38</td>
<td>-0.04</td>
</tr>
</tbody>
</table>

R = Autocorrelation coefficient  
SE = Standard error  
* Correlogram without differencing (d=0).
<table>
<thead>
<tr>
<th>Lag</th>
<th>R</th>
<th>SE</th>
<th>Partial R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.14</td>
<td>0.32</td>
<td>$\phi_{11}$ -0.14</td>
</tr>
<tr>
<td>2</td>
<td>-0.54</td>
<td>0.32</td>
<td>$\phi_{22}$ -0.57</td>
</tr>
<tr>
<td>3</td>
<td>-0.06</td>
<td>0.40</td>
<td>$\phi_{33}$ -0.40</td>
</tr>
<tr>
<td>4</td>
<td>0.20</td>
<td>0.40</td>
<td>$\phi_{44}$ -0.07</td>
</tr>
<tr>
<td>5</td>
<td>0.22</td>
<td>0.41</td>
<td>$\phi_{55}$ -0.23</td>
</tr>
</tbody>
</table>

$R =$ Autocorrelation Coefficient  
$SE =$ Standard error  
* Correlogram without differencing (d=0).

A careful inspection of the above tables indicates that the data (daily scores) are not autocorrelated since a test of significance requires that the ratio $R_k / SE \geq 2$ (at the 0.05 level). It can be observed that none of the coefficients (R), when divided by the standard error (SE), achieved significance. It can then be assumed that throughout the study no serial correlations were observed. This fact has paramount value since it would enable the researcher to use any parametric technique without violating the "classical" requirement of independence between observations. In spite of the failure to observe significant correlation coefficients, special caution should be taken while interpreting the results. It must be kept in mind that the autocorrelograms have been calculated based upon ten data points.
In order to avoid any violation, the series was identified as an ARIMA 0 0 1, which represents a moving average series (Glass and Padia, personal communication). This model is described by Glass, Willson, and Gottman (1975) as:

\[ Z_t - L = a_t - \theta a_{t-1} \]

where \(-1 \leq 0 \leq 1\)

and \( a_t \sim NID (0, \sigma^2) \)

The observation \( Z_t \) could be regarded as dependent upon the current random shock to the series, \( a_t \), and a portion of the previous random shock, \( a_{t-1} \)" (Glass et al., 1975, p. 75).

With this model any "hidden" serial correlation present in the data is taken into account so that "standard techniques" may be used to detect any change in level of the series due to intervention effects.

The TSX program was then used as follows:

(1) a test was requested for change in level of the series due to the intervention period, and

(2) a test was also requested for change in level of the series from baseline to follow-up (See Table 25).

Table 25 indicates that a change in level of the series was caused by the intervention. The mean of the intervention series was significantly increased \((p \leq 0.05)\) with respect to the baseline.
TABLE 25
SIGNIFICANCE TESTS OF CHANGE IN LEVEL OF THE
ACHIEVEMENT SERIES

<table>
<thead>
<tr>
<th>Series</th>
<th>Theta 0</th>
<th>t Statistic</th>
<th>Estimated Level Change</th>
<th>t Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.22</td>
<td>23.25</td>
<td>7.10</td>
<td>2.75*</td>
</tr>
<tr>
<td>Intervention</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>0.54</td>
<td>42.10</td>
<td>16.75</td>
<td>11.09**</td>
</tr>
<tr>
<td>Follow-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05 (df, 18)

**p < 0.01 (df, 18)

Perhaps of more educational significance are the results regarding the baseline and follow-up periods. Table 25 shows that there was a significant \((p < 0.01)\) positive change in level of the series. This may indicate a delayed effect of the intervention observable only during the follow-up.

Regression Analysis. In order to determine the "best fitting line" for testing schedule A during baseline, intervention, and follow-up, regression equations were separately calculated using "day" as the independent variable and mean achievement scores as the criterion variable. The following equations were calculated using the STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES, program REGRESSION (Nie et al., 1975).
\[ Y'_{B} = 0.67 \text{ (day)} + 38.00 \]
\[ Y'_{I} = 1.12 \text{ (day)} + 31.72 \]
\[ Y'_{F} = -0.23 \text{ (day)} + 65.12 \]

Where \( Y'_{B} \) = Achievement during baseline.

\( Y'_{I} \) = Achievement during intervention.

\( Y'_{F} \) = Achievement during follow-up.

Tables 26, 27, and 28 summarize the analysis of variance of regression on students' achievement on baseline, intervention, and follow-up respectively.

**TABLE 26**

ANALYSIS OF VARIANCE OF LINEAR REGRESSION OF STUDENTS' MEAN ACHIEVEMENT SCORES ON GROUP A THROUGHOUT THE BASELINE PERIOD

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>37.3</td>
<td>37.3</td>
<td>2.5</td>
</tr>
<tr>
<td>Residual</td>
<td>8</td>
<td>120.8</td>
<td>15.1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>158.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 27

**ANALYSIS OF VARIANCE OF LINEAR REGRESSION OF STUDENTS' MEAN ACHIEVEMENT SCORES ON GROUP A THROUGHOUT INTERVENTION**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>103.7</td>
<td>103.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Residual</td>
<td>8</td>
<td>719.2</td>
<td>89.9</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>9</td>
<td>822.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 28

**ANALYSIS OF VARIANCE OF LINEAR REGRESSION OF STUDENTS' MEAN ACHIEVEMENT SCORES ON GROUP A THROUGHOUT FOLLOW-UP**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>4.6</td>
<td>4.6</td>
<td>0.06</td>
</tr>
<tr>
<td>Residual</td>
<td>8</td>
<td>662.3</td>
<td>82.8</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>9</td>
<td>666.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The above tables indicate that the regression equation for any period is not significantly different from a horizontal line (See Figure 7). The F value required to achieve significance is 5.32 at the 0.05 level.

**Hypothesis 3, Conclusions.** The hypothesis "There will be a significant change in achievement during the intervention period followed by a down trend during the follow-up period" was tested using a time-series analysis. The results indicate that there was a significant \((p < 0.05)\) positive change in level of the series from baseline to intervention. A significant change in level \((p < 0.01)\) was also found from baseline to follow-up. Since the data were not serially correlated, regression equations were calculated and plotted. The "best fitting lines" show a positive growth during the intervention, followed by a down trend of the series during the follow-up. None of the regressions equations, however, achieved statistical significance.
Figure 7. Achievement throughout Baseline, Intervention, and Follow-up.
Hypothesis 4. The students' attitude pattern toward today's science class will be similar throughout the study.

As with the achievement series, the attitude daily mean scores for group A were analyzed using the CORREL and TSX programs. Tables 29, 30, and 31 show that the data are not autocorrelated at any time (baseline, intervention, or follow-up).

### TABLE 29

**CORRELOGRAM FOR ATTITUDE SCORES**

**BASELINE DATA**

<table>
<thead>
<tr>
<th>Lag</th>
<th>R</th>
<th>SE</th>
<th>Partial R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.27</td>
<td>0.31</td>
<td>$\Phi_{11}$ 0.27</td>
</tr>
<tr>
<td>2</td>
<td>-0.04</td>
<td>0.34</td>
<td>$\Phi_{22}$ -0.13</td>
</tr>
<tr>
<td>3</td>
<td>-0.03</td>
<td>0.34</td>
<td>$\Phi_{33}$ 0.02</td>
</tr>
<tr>
<td>4</td>
<td>-0.08</td>
<td>0.34</td>
<td>$\Phi_{44}$ -0.08</td>
</tr>
<tr>
<td>5</td>
<td>0.05</td>
<td>0.34</td>
<td>$\Phi_{55}$ 0.05</td>
</tr>
</tbody>
</table>

R = Autocorrelation coefficients  
SE = Standard error.  
* Correlogram without differencing (d=0).
### TABLE 30
**CORRELOGRAM FOR ATTITUDE SCORES**

**INTERVENTION DATA**

<table>
<thead>
<tr>
<th>Lag</th>
<th>R</th>
<th>SE</th>
<th>Partial R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.24</td>
<td>0.31</td>
<td>0.24</td>
</tr>
<tr>
<td>2</td>
<td>-0.24</td>
<td>0.33</td>
<td>-0.32</td>
</tr>
<tr>
<td>3</td>
<td>-0.17</td>
<td>0.35</td>
<td>-0.02</td>
</tr>
<tr>
<td>4</td>
<td>0.00</td>
<td>0.36</td>
<td>-0.05</td>
</tr>
<tr>
<td>5</td>
<td>0.09</td>
<td>0.36</td>
<td>0.09</td>
</tr>
</tbody>
</table>

R = Autocorrelation coefficients
SE = Standard error
* Correlogram without differencing (d=0).

### TABLE 31
**CORRELOGRAM FOR ATTITUDE SCORES**

**FOLLOW-UP DATA**

<table>
<thead>
<tr>
<th>Lag</th>
<th>R</th>
<th>SE</th>
<th>Partial R</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.29</td>
<td>0.31</td>
<td>-0.29</td>
</tr>
<tr>
<td>2</td>
<td>0.15</td>
<td>0.34</td>
<td>0.06</td>
</tr>
<tr>
<td>3</td>
<td>0.06</td>
<td>0.34</td>
<td>0.13</td>
</tr>
<tr>
<td>4</td>
<td>-0.01</td>
<td>0.35</td>
<td>-0.11</td>
</tr>
<tr>
<td>5</td>
<td>-0.20</td>
<td>0.35</td>
<td>-0.21</td>
</tr>
</tbody>
</table>

R = Autocorrelation coefficients
SE = Standard error
* Correlogram without differencing (d=0)
Once again the ARIMA model was identified as a 0 0 1 (Glass and Padia, personal communication). The TSX was used, requesting a test for change in level of the series. Table 32 presents the results obtained when the baseline, intervention, and follow-up series were analyzed.

TABLE 32
SIGNIFICANCE TESTS OF CHANGE IN LEVEL OF
THE ATTITUDE SERIES

<table>
<thead>
<tr>
<th>Series</th>
<th>Theta 0</th>
<th>Level</th>
<th>t Statistic</th>
<th>Estimated Level Change</th>
<th>t Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.30</td>
<td>29.41</td>
<td>33.07</td>
<td>0.87</td>
<td>0.70</td>
</tr>
<tr>
<td>Intervention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline</td>
<td>0.12</td>
<td>29.15</td>
<td>36.31</td>
<td>2.31</td>
<td>2.02</td>
</tr>
<tr>
<td>Follow-up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

df = 18

From the above table it can be observed that there were no significant changes in the attitude series due to the intervention. As to baseline and follow-up, Table 32 shows that throughout the study the attitude series remained basically constant. The regression equations for group A corroborate the above statement.

Regression Analysis. The baseline, intervention, and follow-up periods for testing schedule A were analyzed using a regression procedure. "Day" was considered the independent variable, whereas attitude scores were used as the criterion variable. The following
equations were calculated using the STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES program REGRESSION.

\[ Y'_B = 0.49 \text{ (day)} + 26.46 \]
\[ Y'_I = 0.37 \text{ (day)} + 24.77 \]
\[ Y'_F = 0.40 \text{ (day)} + 21.20 \]

Where:

\[ Y'_B = \text{Attitudes during baseline.} \]
\[ Y'_I = \text{Attitudes during intervention.} \]
\[ Y'_F = \text{Attitudes during follow-up.} \]

Tables 33, 34, and 35 summarize the analysis of variance of regression on students’ attitudes throughout baseline, intervention, and follow-up respectively.

**TABLE 33**

**ANALYSIS OF VARIANCE OF LINEAR REGRESSION OF STUDENTS’ MEAN ATTITUDE SCORES ON GROUP A THROUGHOUT THE BASELINE PERIOD**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>20.4</td>
<td>20.4</td>
<td>4.6</td>
</tr>
<tr>
<td>Residual</td>
<td>8</td>
<td>35.2</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>55.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 34
ANALYSIS OF VARIANCE OF LINEAR REGRESSION OF STUDENTS' MEAN ATTITUDE SCORES ON GROUP A THROUGHOUT THE INTERVENTION PERIOD

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>11.3</td>
<td>11.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Residual</td>
<td>8</td>
<td>27.2</td>
<td>3.4</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>38.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### TABLE 35
ANALYSIS OF VARIANCE OF LINEAR REGRESSION OF STUDENTS' MEAN ATTITUDE SCORES ON GROUP A THROUGHOUT THE FOLLOW-UP PERIOD

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>13.2</td>
<td>13.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Residual</td>
<td>8</td>
<td>79.2</td>
<td>9.9</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
<td>92.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The critical value required to achieve significance at the 0.05 level is 5.32. The regression equations were then plotted having "days" on the abscissa, and mean attitude scores on the ordinate. Figure 8 depicts the best fitting lines.

Figure 8. Attitudes Throughout Baseline, Intervention, and Follow-up for Group A.
Hypothesis 4. Conclusions. The hypothesis "Students' attitude pattern toward the science class will be similar throughout time" was accepted. This hypothesis was tested using a time-series analysis. The results indicate that no significant changes in the level of the attitude series were present from baseline to intervention nor from baseline to follow-up. The regression equations calculated for each period indicate that attitude scores fit regression equations which do not differ from a horizontal line.

Summary of Results. The results of the analyses conducted to test the four hypotheses indicate that:

1. Students' mean performance on the objectives of the crustal evolution unit was similar regardless of the testing schedule.
2. Students' mean attitudes toward today's science class were also similar regardless of the testing schedule.
3. There was a significant (p < 0.05) positive change in level of the achievement series from baseline to intervention, followed by a slight no significant down trend during the follow-up period.
4. Attitudes throughout the study remained practically constant. No significant differences were found from baseline to intervention, or from baseline to follow-up.
CHAPTER V

SUMMARY, DISCUSSION OF RESULTS, CONCLUSIONS
AND RECOMMENDATIONS

Summary of the Study

Traditionally time-series designs have been used in business forecasting areas, managerial fields, and clinical psychology. Campbell and Stanley (1963) presented this design to the education community as a quasi-experimental design able to eliminate some of the "threats" to validity common to traditional designs.

Recent studies using time-series designs (Mayer and Kozlow, 1979; Mayer and Lewis, 1979) created a need for a study of the validity of "intensive" time series designs. A concern expressed by Mayer and Kozlow (1979) was that repeated testing over relatively long periods of time might affect the validity of the measurements of concept understanding.

Problem. This study was aimed at assessing the effects, if any, of frequency of testing upon the measurement of achievement on a crustal evolution unit, and the measurement of attitudes toward the science class. Studies by Lane et al., (1977) and Mann et al., (1970) suggest that retesting may enhance learning; that is, students may learn from taking the tests, thus decreasing the validity of the results. In
regard to attitudes, Catanzano and Wilson (1977) found that students who have been exposed to optional retest situations had significantly better attitudes toward the school, science, and retests, than did those in mastery retesting schedules.

In an intensive time-series design, testing is conducted over long periods of time hence, learning may be enhanced, apathy toward the instrument may result, and attitudes toward the science class may be drastically reduced.

Population. Four intact earth-science classes were selected to participate in the study. The school is located near Columbus, within a community of middle to upper socio-economic status. The students were enrolled in the eighth grade and were taught earth-science by the same teacher.

Design. Students within each of the four classes were randomly assigned to one of three testing schedules. Students assigned to testing schedule A were tested every day for 30 days. Students on testing schedule B were tested about every four days, and students on testing schedule C were tested about every ten days. A multiple-group—single intervention time-series design (Glass, Willson, and Gottman, 1975) was used to assess the effects of frequency of testing upon the measurement of achievement on a crustal evolution unit, and attitudes toward today's science class. This design is presented by Glass et al., (1975) as having a baseline, or no treatment period, followed by an intervention, and then a follow-up period.

During the first two weeks of the study, the students were taught mineralogy and petrology. This period of time was used as baseline.
Then an intervention period which lasted two weeks was introduced. During the intervention a crustal evolution unit prepared for this study was taught by the teacher. Then, a follow-up period which lasted two weeks was devoted to the study of oceanography. Testing occurred throughout the baseline, intervention, and follow-up periods.

**Instruments and Data Collection Procedures.** According to their testing schedules, students received an instrument which consisted of two questions randomly drawn one from an achievement pool, and one from an attitude pool. The achievement pool which consisted of 66 multiple-choice items was developed to assess performance on the three objectives of the crustal evolution unit. The eleven semantic differential items forming the attitude pool were intended to measure attitudes toward today's science class.

An achievement post-test was given to all the students on day 21. Two forms were designed, A, and B. Each form had 39 items, twelve of which were common to both forms. Post-test analyses were conducted to assess the reliability of \( K_{20} \) of the two forms. The difficulty level of each question was determined and a daily mean item-difficulty level was calculated and plotted.

The whole attitude pool was given on day 30. Reliability measures were determined (Hoyt) using the FORTAP computer program.

Campbell in 1969 added to his list of threats to internal validity "instability" which he defined as "...unreliability of measures, fluctuations in sampling persons or components, and autonomous instability of repeated or equivalent measures" (p. 411). In order to obtain measures of reliability of the post-test forms, an item analysis
was performed. The results indicate that the post-test instruments were reliable. Thus, the possibility of an unreliable test threatening the validity of the results was eliminated.

The Hoyt reliability of the attitude pool was determined using the FORTAP computer program. The results of the analysis of variance conducted with the whole population, or with each testing schedule separately indicate that the attitude instrument was highly reliable, thus ruling out the possibility of "instability of measures" as a threat to internal validity.

A major concern was also to determine if the fluctuations observed during the intervention and follow-up periods were due to the nature of the items selected for those days, or if indeed they represented changes in the performance of the students with respect to the crustal evolution unit. The plot of daily mean item difficulty as determined from the post-test item-analyses strongly rules out the possibility of instrumentation being responsible for such fluctuations. Thus, it would be fair to conclude that changes in mean achievement scores are likely to be caused by the intervention.

Discussion of Results.

Hypothesis 1. Students' mean performance on the crustal evolution unit will be similar regardless of the testing schedule.

In order to assess if statistically significant differences were present between testing schedules, analysis of variance was conducted on achievement scores obtained on those days in which all the students had been tested. The results of the analysis of variance indicate that only
the mean achievement score obtained by testing schedule C on day 21 was significantly different from the mean achievement score obtained by testing schedule B (p < 0.05). The remaining differences on days 1, 21, or 30 were not significant.

There does not seem to be a clear pattern or relationship between achievement scores obtained by students on testing schedules A and B. Even though six times students on testing schedule B outperformed those on testing schedule A, the differences were slight, with less than five percentage points difference on four occasions.

The comparison of students on testing schedule C and A indicates that the former outperformed students on testing schedule A every time both groups were tested. None of the differences, however, was statistically significant.

"Mortality" is also regarded by Campbell and Stanley (1963) as a threat to internal validity. Absenteeism on a given day implies that the population being tested changes from day to day. Furthermore students who are absent may not be representative of the whole population, thus the results obtained may be misleading. To eliminate the concern of having different populations on days 1, 21, and 30 mean achievement scores on those days were also calculated for only those students who were present on all of the three common testing days. Mean achievement scores indicate that students on testing schedule C outperformed those on testing schedule A on each of the three common days. Similarly, students on testing schedule B outscored their peers on testing schedule A every time common testing was present. On day 21, students on testing schedule C outperformed those on testing schedule B,
on the remaining two days students on testing schedule B and C obtained the same mean achievement scores. The analyses of variance conducted to assess the mean achievement scores on days 1, 21, and 30 indicate that none of the mean differences were significantly different from each other. The pattern observed when only the same students were analyzed tends to support the hypothesis of no effects on achievement on the crustal evolution unit due to frequency of testing. These results suggest that daily mean achievement scores might have been influenced by the academic characteristics of students present on a given day. Hence, precautions should be taken to assure that the same populations are compared.

Additional analysis on day 21 was conducted using the scores obtained with the post-tests. The mean achievement differences were assessed using a 3 X 4 analysis of variance procedure. The results indicate that no significant differences were present among mean achievement scores by testing schedule.

Campbell and Stanley (1963) regarded "testing" as a threat to internal validity. Cook and Campbell (1979) state that "... familiarity with a test can sometimes enhance performance because items and error responses are more likely to be remembered at later testing sessions" (p. 52). In this study testing does not seem to influence the results. If this were the case we would have seen higher mean achievement scores on testing schedule A than on testing schedule B or C. It should be kept in mind that the randomization procedure took care of this threat by assigning different questions every day, thus eliminating the possibility of learning from testing. Perhaps the decision to withhold
knowledge of results helped to control for the unwanted influence of testing on achievement scores.

Based upon the results obtained when the three testing schedules were compared to each other, it would be accurate to state that achievement scores were not affected by frequency of testing.

**Hypothesis 2. Students' mean attitude scores will be similar regardless of the testing schedule.**

A careful examination of Figure 6 seems to indicate that there is not a systematic difference in attitude patterns among the three testing schedules. The results of the analysis of variance performed on mean attitude scores obtained on days 1, 21, and 30 found no significant differences among testing schedules.

Mean attitude scores on day 30 indicate that students on testing schedules A and C obtained practically the same scores. Attitude scores for testing schedule B were slightly lower. The lack of an attitude pattern followed by the three testing schedules would argue against a possible "resentment or demoralization" factor as proposed by Cook and Campbell (1979). Had there been a hypothetically less desirable "testing schedule," attitude scores would have shown larger differences among the three testing schedules. The data collected do not seem to support this "threat." On the contrary, the data suggest that students' attitudes were not influenced by the fact that they were assigned to a given testing schedule. The interviews conducted of twelve of the students strongly support the claim that students' attitudes toward the science class were not changed by the crustal evolution unit, nor by the particular testing schedule to which students were assigned.
Since the attitude question always followed the achievement question, it may be argued that the attitude scores obtained represent the degree of success or failure on the achievement question rather than attitudes toward the concept "Today's science class." This threat to the validity of the attitude instrument was eliminated by the lack of correlations between daily achievement and attitude scores.

**Hypothesis 3.** There will be a significant change in achievement during the intervention period followed by a down trend of the achievement series during the follow-up period.

Achievement scores obtained on students forming testing schedule A were anlayzed. A visual inspection of Figure 7 shows a gradual increase or change in achievement from baseline to intervention. This change is noticeable on days 14, and 19 where sudden "jumps" set a new series level. The inspection of the total series seems to indicate that there is a delayed intervention effect followed by a slight down trend during the follow-up period. With the aid of correlograms, an ARIMA model was identified (0 0 1) and tested for changes in level of the series from baseline to intervention, and baseline to follow-up. The time-series analyses indicate that there was a significant (p ≤ 0.05) change in level of the series from baseline to intervention. A more drastic change in level (p ≤ 0.01) was detected from baseline to follow-up.

The results seem to indicate that achievement or learning growth does not occur immediately after the intervention period is started. Instead a sudden "jump" in achievement occurs several days after and even continues for a few days into the follow-up period.

In order to determine if achievement on a given day during the intervention period was influenced by whether or not the questions
selected for that day had already been covered, a Pearson Product Moment Correlation Coefficient was calculated. There does not seem to be any correlation between achievement on the item pool and whether or not the questions asked had been covered.

A possible explanation may be that the information or material presented during the first days of the intervention is simply stored by the students without any real addition to previously learned concepts. This lack of "anchorage" (Ausubel, 1963) may be delayed until enough relevant information is added to the students' mental structure so that it can be stored, organized, and eventually learned. Only then, the students might be able to show changes in learning. This process may last several days, or even weeks, depending upon the nature of the concept being taught.

Another possible explanation for the "delayed achievement" may be related to the kind of questions asked every day. Chances are that only those questions requiring the recollection of facts (memorization) may be answered correctly the same day that they were covered by the teacher, whereas a question whose nature requires analysis, evaluation, synthesis, or comprehension may only be answered correctly after more detailed and related concepts are presented to the students. The results of this study suggest that the questions asked throughout the investigation required a high cognitive level thought process such as analysis, or synthesis, hindering early changes in achievement.

The follow-up period was characterized by a slightly negative sloped regression line. The "forgetting" period associated with the withdrawal of the intervention does not seem to start until after day 25,
that is, eight days including the three days devoted to the history fair. There seems to be a carry-over effect from intervention to the middle of the follow-up period, suggesting that learning is occurring even after the intervention has ceased. Mayer and Kozlow (1979) also detected this pattern which they described as "momentum effect."

**Hypothesis 4.** The students' attitude pattern toward the science class will be similar throughout time.

Attitude scores from students comprising testing schedule A were analyzed. A visual inspection of Figure 8 reveals that attitudes toward the science class oscillate around a constant mean level. In order to determine changes in level of the series due to intervention effects, a time-series analysis was used. An ARIMA model (0 0 1) was also identified and tested for significant changes in level. No significant changes in level of the series were found from baseline to intervention, nor from baseline to follow-up. The regression equations support the conclusions drawn from the visual analysis, and from the time-series analysis.

Students' attitudes toward the science class could have ranged from 1.0 (negative) to 5.0 (positive). A score of 3.0 would represent a neutral position. From Figure 8, it can be observed that students on testing schedule A reacted in a slightly negative way toward most of the science classes. The overall mean attitude score obtained for testing schedules B and C was 2.9, indicating that there was a slight negative posture toward the science class which remained unchanged by the intervention or follow-up periods.
Conclusions.

The visual analysis of achievement and attitude data, as well as the statistical analyses conducted, lead to the following conclusions:

1. Students' mean achievement scores are not affected by the frequency by which the students are tested. This finding does not support the results of earlier studies in which testing enhanced learning. However, it should be kept in mind that students participating in this study received a different instrument every day, whereas earlier studies used the same or equivalent instruments.

2. Students' mean attitude scores are not affected by the frequency by which students are tested. Catanzano and Wilson (1977) claimed that students' attitudes were significantly better for those in optional retesting schedules than for their peers in mastery retesting schedules. Even though in this study there was not an optional retesting schedule, it could be assumed that students having less testing should have reacted more positively toward the science class. Again this was not the case. It seems as if the "intensive" but nonetheless short testing does not affect students' attitudes. After the first two or three days the students regarded the "testing procedure" as a normal routine part of the science period.

3. The design used in this study was capable of identifying expected changes in students' understanding of the crustal evolution concept as a result of instruction. That is, learning growth during the intervention period, followed by a slight decline due to the withdrawal of instruction. This pattern agrees with the established literature regarding the learning of information.
4. Three units were used in this study: mineralogy and petrology during the baseline period, crustal evolution during the intervention period, and oceanography during the follow-up. The fact that daily mean attitudes did not change supports the idea that students' attitudes are not affected by the topic being introduced.

5. As to the use of an intensive time-series design, this study leads to the conclusion that a time-series used in an intensive study is a valid design able to eliminate "threats" which may otherwise affect the validity of the results. Furthermore, this study indicates that a time-series design is an accurate and powerful tool for close monitoring of students' behaviors, and learning growth. This design has also been shown to be able to detect retention patterns so frequently disregarded by "conventional" designs.

Recommendations.

1. A replication of the study is highly recommended. A similar study could reinforce the claim of no significant differences between testing schedules on achievement and attitude scores. It may be argued that the attitude instrument was not sensitive enough to detect students' attitude changes toward the science class. The sensitivity of the instrument can be determined by provoking a known negative (test) or positive (field trip) attitude response from the students. A sensitive instrument should be able to detect changes in students' attitudes when either a field trip, or a test is used. Another possibility for checking the sensitivity of the instrument would be to use it with different concepts such as science, school, teacher.
2. In this study as well as in those conducted by Mayer and Kozlow (1979) and Rojas (1978), there seems to be a common learning pattern followed by the students. This design can be used to identify learning patterns of students having different mental characteristics.

3. The use of an intensive time-series design combined with a detailed observational system of instructional analysis (OSIA) such as that developed by Hough (1976) might provide invaluable information regarding the relationship between students' achievement and attitudes and the instructional characteristics present in the classroom.

4. As to the analysis of time-series data, it is recommended to look for additional statistical procedures able to detect "immediate" changes in the series. Algina and Swaminathan (1979, 1977) suggested a multivariate approach. Their procedure besides accounting for serial correlation present in the data, tests the hypothesis that 
"... the r population means lie on a straight line, or equivalently the hypothesis that the treatment is not effective" (Algina and Swaminathan, 1977, pp. 56-61). This hypothesis can be tested using the Hotellings $T^2$, or be transformed into the familiar F test. The procedure can be used with less data points that the ones required for the CORREL and TSX programs.

5. A methodological recommendation would be that special care should be taken to assure that some of the questions selected to be asked on a given day should be related to the material covered that day on the science period. Questions should also represent different levels of the cognitive domain such as knowledge, comprehension, analysis, and evaluation.
6. A common practice by school teachers and even college professors is to test their students immediately after a unit or major topic has been covered. If learning is still taking place, even after the teaching has ceased as this study suggests, perhaps the post-tests should be given a few days after the unit or topic has been completed so that the maximum point on the learning curve may be reached. Similarly, research designs using post-tests should delay the use of them for a few days after the treatment is completed. In this way, post-test outcomes might be more representative of students' achievement.

7. "Mortality" as defined by Campbell and Stanley (1963) may lead to erroneous conclusions. In this study, changes in populations due to absenteeism seem to affect daily achievement scores as well as the pattern followed by each testing schedule. Careful records of absenteeism must be kept. It will be highly desirable to analyze only the results of those students who were always present during the study, provided this procedure does not reduce the sample size to statistically inappropriate n's. Students' academic characteristics such as IQ, reading scores, science achievement scores and mathematics scores should be considered in further research using a time-series design. If different populations should be tested due to absenteeism, adjustment of scores through analysis of covariance might be necessary.

8. Further research should concentrate on the "carry-over" effect observed after the intervention is withdrawn. Is this effect characteristic of learning curves, or is the "carry-over" effect intrinsic to time-series designs? Factors affecting the length of the carry-over
effect may be identified, the relationship between events present in the classroom and the carry-over effect should be studied. Instructional strategies capable of maintaining learning after the intervention has been withdrawn are worthy of consideration by future researchers.
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CRUSTAL EVOLUTION UNIT

OBJECTIVES.

Students will be able to understand the earth as a dynamic system, in which crust is being produced at the ridges and destroyed at the trenches.

A. Students will be able to describe the major types of evidence that lead scientists to the plate tectonics theory.

1. Students should be able to match the continents as they might once have fitted together.

2. Students will determine the best fit of the continents of South America and Africa, first by using shape and then by using the patterns of rocks.

3. Students will determine the best fit of South America, Africa, India, Australia, and Antarctica where data from direction of movement of glaciers is taken into consideration.

4. Students will be able to locate some of the main topographic features of the Atlantic Ocean.

5. Students will understand that fossil magnetism has been used as evidence of sea-floor spreading.

6. Students will be able to determine magnetic orientation of "rocks" making up the sea floor.

B. Students will be able to describe the results of the processes that occur at plate boundaries, and the evidence of those processes.

1. Students should be able to associate volcanoes to production of new crust.
2. Students should be able to consider volcanoes as consequence of dynamic processes undergoing in the earth's interior.

3. Students should be able to relate earthquakes to plate boundaries.

C. Students will be able to explain the mechanism most scientists currently think cause crustal plates to move.

1. Students will be able to sketch the circulation pattern of a convection cell.

2. Students should be able to relate convection cells to sea-floor spreading and continental drift.
CRUSTAL EVOLUTION
(Teacher's Guide)

The first day the teacher should give a brief introduction to the concept of crustal evolution.

Introduction.
This unit that we are about to start, deals with the changes in the earth's crust.

Crustal evolution is today one of the most attractive subjects among scientists. It deals with the production and destruction of crustal materials as well as the implications of such changes.

For many years scientists have noted the similarities of the East coast of South America and the West coast of Africa. Could these continents have once been together? .... if so, why did they split?

On the other hand.... for many years man has witnessed the destruction caused by earthquakes and volcanoes. Why do they occur?

Is there any relationship between earthquakes and volcanoes and the production or destruction of crustal material?

If the continents were once together, what was the role of earthquakes and volcanic activity in their separation?

These are some of the questions that we will try to answer while developing our crustal evolution unit....

... After this introduction, hand out the objectives of the unit.
... Go over the objectives of the unit.
... then, introduce the first activity.
Jigsaw Puzzle
(Teacher's Guide)

A. Activity

Objectives: At the end of the activity the students should be able to match the continents as they might once have fitted together.

Materials: Continents
Scissors
Cardboard

Directions: 1. Introduction: Let's suppose that we have a puzzle, our pieces are the continents. As in any puzzle one should try to find the best fit for all the pieces.

2. Hand out the student's guides.

3. Read the objectives.

Answers to questions:

1 - 

2 - 

3 - 

B. Slides and Discussion.

After the students have finished the activity, hand out a set of questions, these are to serve as guides for the students during the slide presentation.

Allow students sufficient time during the discussion to answer the questions on the student's guides.

C. Evaluation

Students should be made aware of the fact that the answers to the questions on the activity and students' guide will be graded.
Jigsaw Puzzle
(Student's Guide)

Objective: At the end of the activity the students should be able to match the continents as they might one have fitted together.

Materials: Continents
Scissors
Cardboard

Introduction: Today, we are going to reconstruct a single super-continent which could have existed 200 million years ago. This super-continent is called Pangea.

Procedure: 1. Cut out the continents from the map given by your teacher.

2. Consider each continent as a piece of a puzzle. Try to solve your puzzle fitting the continents together along their coast-lines.

3. When you are satisfied that you have found the "best fit", tape your continents together.

Questions: 1. In several areas you may have one continent on top of another. How can you explain these areas of overlap?

________________________________________________________________________

________________________________________________________________________

2. In several areas, you may have zones of gapping or spaces between continents.
   How can you explain these areas of gapping between continents?
   ________________________________________________________________________
   ________________________________________________________________________
   ________________________________________________________________________

3. The matches of continental borders which you have made are reasonably good.
   What can you conclude from this?
   ________________________________________________________________________
   ________________________________________________________________________
   ________________________________________________________________________
MATCHING CONTINENTS ACROSS THE ATLANTIC OCEAN

Cut along the dashed line.
JIGSAW PUZZLE

(TRANSCRIPT)

Ever since man was able to travel around the world, he realized that the oceans were interconnected, but the continents were not.

For many centuries scientists have wondered if the continents and oceans have always remained still or if they have shifted from previous positions.

At the beginning of the 20th century, a German scientists named Alfred Wegener, proposed what we can consider one of the most revolutionary theories of the earth sciences.

Based upon the striking similarities of South America and Africa across the Atlantic ocean as well as several evidences found on the continents, Wegener thought that the continents might once have been together forming a single landmass, which he called Pangea.

This super-continent could have existed 200 million years ago. Compare Wegener's idea about the continents with your puzzle. Does your puzzle support or reject Wegener's idea?

According to Wegener, continents began to split apart and drift in different directions.

Observe the positions of India, Australia, North America, and South America.

In which direction did India move? In which direction did Australia move? In which direction did South America move?

As you can see, India traveled an enormous distance, until it collided with Asia.

What geographic feature could be formed if two landmasses collide?

Do you find any evidence of the collision of India with Asia?
Jigsaw Puzzle - Slide Discussion

(Student's Guide)

Answer the following questions:

1. Who was Alfred Wegener? _______________________________________________

2. Does your puzzle support or reject Wegener's ideas? ________________

3. According to Wegener's theory, in which direction did India move? __
   In which direction did Australia move? ______________________________
   In which direction did South America move? _________________________

4. What geographic feature might be formed if two landmasses collide? __

5. Is there any evidence supporting that India might have collided with Asia? ________________
Activity

Objectives: 1. Students will determine the best fit of the continents of South America and Africa, first by using shape and then by using the pattern of rocks.

2. Students will determine the best fit of South America, Africa, India, Australia, and Antarctica, where data from direction of movement of glaciers is taken into consideration.

Materials: Continents.

Directions:

Introduction: While doing a jigsaw puzzle the shape as well as the color of the pieces are very important.

Similarly while fitting the continents together, one should consider the shapes as well as the rocks making up the East coast of South America and the West coast of Africa.

Several studies have been conducted on these continents in order to determine the age and type of rocks present.

Hand out student's guides.

Read the objectives and introduction to the student's guide. Begin activity.

Answers to questions on page 1:

1. When you do a jigsaw puzzle, how do you decide if two pieces fit together? (What two things are used?)

   A. Shape.

   B. Color.

2. In the last activity, what was the only thing which was used?

   Shape.
3. What could be used to check if South America and Africa were once joined together?

The kinds and ages of rocks on either side of the ocean should match. Their pattern (that is, the trends of the mountains or folds) should match.

Answers to questions on page 2:

1. When South America and Africa are fitted together, how well do the ages of the rocks match?

The units in the northern part fit well. The "dish-shaped" area of 2000 million year old rocks (points 4, 5, and 6) of South America match well with the 2000 million year old rocks of Africa (points 24 to 27).

The contact and rock units of point 1 of South America match exactly with the contact and rock units of point 24 of Africa.

A match of the "older than 2600" rocks of point 9 of South America can be made with rocks of the same age at point 31 of Africa.

The units in the southern parts do not fit well. The 1000 million year old rocks of Africa can not be matched to any corresponding rocks of South America.

The 225 million year old rocks at the tip of Africa do not match with rocks of South America, although there is a hint of a match with the 2000 million year old rocks.

2. When the continents are fitted together, how well do the folds of the rocks match?

The trends of the folds and the contacts actually match better than the rock units. However, some in southern Africa do not exactly match those of South America.

3. Does the evidence from the rocks tend to prove or disprove the idea that the continents may have fitted together?

The students should reach the conclusion that the evidence is pretty good that South America and Africa may have been one continent in the geologic past.

4. Can you think of any reasons why the evidence is not better? The main problem is the lack of good geologic data.

Five reasons are given on page 1 of the student's guide
why information is lacking on the older rocks.

In the second part of the activity, the students will study glacier marks and direction of ice movement which has been used as evidence supporting continental drift:

Introduction: It is thought that before the split of the continents, parts of South America, Africa, Antarctica, Australia, and India were glaciated.

Hand out the student's guides.

Tell the students that the arrows represent direction of ice movement.

Students will try to find the best "fit" based upon shapes and glacial evidence.

Answer to questions:

1. How well do continents fit?

Quite well. Some gaps and overlaps occur, particularly where the southern tips of Africa and South America are fitted to the long peninsula of Antarctica. There is a question whether this peninsula has always been part of Antarctica.

2. How does the evidence of glaciation relate to the idea that all the landmasses were joined at the same time to form a "super-continent"?

The distribution of the glacial deposits and the direction of the ice movement do not make much sense when we look at these features of South America, Africa, Antarctica, and Australia, and India in their present geographic position. However, if these continents are "reunited" to form Gondwanaland, the areas of glacial deposits are connected and the direction of ice movement suggest that the ice radiated away from a center located in ancient Antarctica.

3. Using the map of Gondwanaland which you have just made, what would be the latitude of southern India at the time of the Permo-Carboniferous glaciation? (Assume that the South Pole is in the correct position and estimate the positions of the latitude lanes.)

The latitude would be 60°-65° South. Counting the first ellipse as 80° S and the second one (only partly shown) as 70° S, the 60° S latitude line (using the same spacing) would cross the middle part of India.
Slides and Discussion:

1. Distribute the questions to be answered while the slides are being shown.

2. Start slide presentation.
The diagram is based on Smith and Hallam (1970). The stippled pattern shows the distribution of known Permo-Carboniferous glacial deposits. Arrows indicate the direction of ice movement.
ADDITIONAL EVIDENCE  
(Student’s Guide)

Activity:

Objectives: 1. Students will determine the best fit of the continents of South America, and Africa, first by using shape and then by using the pattern of the rocks.

2. Students will determine the best fit of South America, Africa, India, Australia, and Antarctica where data from direction of movement of glaciers is taken into consideration.

Materials: Continents.
Scissors.
colored pencils.

Introduction: 1. When you do a jigsaw puzzle, how do you decide if two pieces fit together.
What two things are used? A__________
B__________

2. In the last activity, what was the only thing which was considered?

3. What could be used to check if South America, and Africa were once joined together?

Just as the pattern and color of jigsaw pieces match, the patterns and kinds of rocks along the coasts of Africa, and South America should match, if these continents were once joined. Geologists have mapped much of South America and Africa to find out about the kinds, ages and folding of the rocks. For our study we will use data only on the age and folding.

Will the ages of all the rocks match? No, because some of the rocks may have formed after Africa, and South America separated. The only rocks which should match would be those which were present before the split occurred. As the split is thought to have happened about 200 million years ago, only rocks older than 200 million years can be expected to match. This makes the study difficult because it is hard to prove that rocks this old are the same. Fossils, which are used to match younger rocks, are absent. Most of the rocks along the coast of South America and Africa are much older than any fossils. Their ages can be found by chemical studies of the radioactive minerals found in the rocks.

Besides comparing the ages of the rocks, we also can compare how they are folded. If the rocks were folded to form ridges or mountain ranges, the directions of the ridges or mountains should match.
Data on the older rocks at some places are incomplete. There are at least five reasons for this. (1) the older rocks may have been eroded away. (2) The older rocks may be covered by younger rocks, or sediments, and can not be studied. (3) the older rocks may have been so changed by heat and pressure that they can not be dated chemically. (4) No older rocks were deposited at a particular place. (5) No one has studied the area to obtain all the data about the rocks.

Procedure: Data from rocks present in South America, and Africa have been plotted on the "continents" which will be given by your teacher.

Rocks at different locations have been studied for several years. Scientists have determined their ages as well as their general characteristics (trend, composition, color, etc)

Fit the land masses together using their shapes, ages, and characteristics.

Questions: 1. When South America, and Africa are fitted together, How well do the ages of the rocks match?

______________________________________________________

______________________________________________________

______________________________________________________

2. When the continents are fitted together, how well do the trends of the rocks match?

______________________________________________________

______________________________________________________

3. Does the evidence from the rocks tend to prove or disprove the idea that continents may have fitted together?

______________________________________________________

______________________________________________________

4. Can you think of any reasons why the evidence is not better?

______________________________________________________

______________________________________________________
In this part of our study we will consider evidence left by a large continental glacier which covered parts of South America, Australia, Antarctica, Africa, and India.

The deposits left by the glacier have long since changed to rocks. These can be mapped to show where the glacier was. The moving glacier left scratches and marks on the older rocks. From these marks it is possible to tell which way the ice moved.

One strange fact was found. India which is now near the equator and has a hot climate, was covered by ice during this time. Even odder the ice came from the south (the present equator) and moved north toward the mountains. This is just the opposite of what you might expect.

Procedure: 1. The models given by your teacher show the direction in which the ice moved in South America, Africa, Antarctica, Australia, and India.

2. Fit the land masses together, using their shapes and glacial evidence as guides.

Questions: 1. How well do the continents fit together? ________________

2. How does the evidence of glaciation relate to the idea that all the land masses were joined together at the time to form a "super-continent"? ________________

3. Using the map of Gondwanaland which you have just made, what would be the latitude of southern India at the time the Permo-Carboniferous glaciation? (Assume that the South Pole is in the correct position and estimate the positions of the latitude lines). ________________
For this investigation you do not need to cut out the western side of South America.
Small dots show the general areas where Permo-Carboniferous glacial deposits have been found.
Small dots show the general areas where Perm-Carboniferous glacial deposits have been found. As the ice cap covers most of the rock, the evidence is limited. Other glacial deposits of this age probably lie beneath the ice.
For several years scientists have been searching on the continents for evidence which can support the continental drift theory.

In this part of the unit, we have studied how glacial striations or marks left by glaciers are indicative of the direction in which the ice moved. Furthermore, we have seen that these glaciation patterns make more sense when South America, Africa, India, Antarctica, and Australia are joined together forming a super-continent.

On the other hand, we have seen that some rocks making up the eastern part of South America have several characteristics (age, type, trend) which are similar to those rocks present on the west coast of Africa, suggesting that evidently the continents could have been together.

Similar studies have been undertaken with respect to the Appalachian mountains in North America and the Caledonian Mountains in Europe.

Like some of the rocks in South America, and Africa, the Appalachian and Caledonian mountains trend in the same direction.

Plant and animal remains (fossils) have played an important role in helping to solve the puzzle of the continents.

*Lystrosaurus*, a species which existed approximately 180 to 225 million years ago was discovered in Antarctica and other areas of the world. Since this "LAND ANIMAL" could not have crossed the intervening oceans, the existence of a super-continent is a possible explanation for its wide-ranging distribution.

Similarly, the only possible explanation to some plant fossils and microorganisms found on different continents is "continental drift" and until better explanations are given, this theory will withstand its opponents.
ADDITIONAL EVIDENCE
(Student's Guide)

Answer the following questions:

1. What evidence do geologists have supporting the presence of glaciers several million years ago?

2. Why could India have not been glaciated in its actual geographic position?

3. How does the evidence of Permo-Carboniferous glaciation relate to the idea that all the land masses were joined together at that time?

4. Why do swimless animals found on several continents support the drifting of the continents?
TOPOGRAPHY OF THE SEA-FLOOR

(Teacher's Guide)

Objective: Students will be able to locate some of the main topographic features of the Atlantic Ocean.

Materials: Atlantic Ocean map.

Directions: 1. Introduction.

For centuries people thought that the ocean basins were featureless plains. However, with the aid of equipment scientists have discovered that the oceans have very prominent features like: mountain chains, volcanoes, canyons, plains, sea mounts.

Today we will study the location of some of the main features as well as their characteristics.

2. Distribute the student's guide.

3. Read the objective of this activity.

Note: some students may get confused while observing that there are numbers (elevations) with negative or positive signs. Thus additional explanation in terms of features above or below sea level would be helpful.

Answer to questions:

2. The continental shelf is found on the East coast of South America.


4. Values ranging from -250 to -330 ft. below sea level.

5. 17,400 ft. below sea level.

   1. Hatteras Abyssal plain
   2. Nares Abyssal plain
   3. Demerara Abyssal plain
   4. Pernambuco Abyssal plain
   5. Argentine Abyssal plain
   6. Biscay Abyssal plain
   7. Gambia Abyssal plain
   8. Angola Abyssal plain
   9. Ceara Abyssal plain
Teacher's Guide (continuation).

7. Volcanic activity.

8. They have a volcanic origin. Volcanic islands which sink and become sediment-capped seamounts.

9. Sea mounts are below sea level.

10. It is a mountain chain along the Atlantic Ocean, with a great deal of relief.

11. Iceland is part of the Mid-Atlantic Ridge.

The Mid-Atlantic Ridge is above sea level and Iceland is the best sample.
TOPOGRAPHY OF THE SEA FLOOR

(Student's Guide)

Objective: Students should be able to locate some of the main topographic features of the Atlantic Ocean.

Materials: - Atlantic Ocean map.

Activity: 1. Examine the map of the Atlantic Ocean provided by your teacher. Find the following areas located off the eastern coast of the U.S.A.: The grand Banks, and the Blake Plateau. These are located on a feature called the Continental Shelf.

2. Locate a Continental Shelf on South America. Where did you find it? __________________________________________

3. What islands are located on the European Continental Shelf? __________________________________________

4. What is the relative depth of water over the continental shelf? __________________________________________

5. Locate the Sohm Abyssal plain off the coast of the U.S.A. What is the relative depth of water over this feature? __________________________________________

6. How many other abyssal plains located on the Atlantic Ocean floor have been named? __________________________________________

7. Locate the following island groups: The Azores, Canary Islands, Cape Verde Islands, Ascension, Tristan da Cunha. How do you think they were formed? __________________________________________

8. Locate several groups of sea mounts. How do you think they were formed? __________________________________________
9. How are they different from the Islands you have located?

10. Locate the Mid-Atlantic Ridge. Describe it briefly.

11. Where is Iceland in relation to the Mid-Atlantic Ridge?
PALEOMAGNETISM
(Teacher's Guide)

A. Activity

objectives: Students will understand that fossil magnetism has been used as evidence of sea-floor spreading.

Students will be able to determine magnetic orientation of "rocks" making up the sea-floor.

Materials: Plaster model of the sea floor.
Compass
Adding machine tape.

Directions: 1. Introduction: There are several techniques which have been used while studying the sea-floor. One of these methods has to do with the magnetic properties of rocks. This is the ability of a mineral to attract or reject a compass needle.

The study of magnetic properties of rocks formed millions of years ago is called "Paleomagnetism".

2. Hand out the student's guides.

3. Read the objectives.

4. Each model can be shared by four students.

Due to the fragility of the models, the students ought not lift nor move them.

5. Tell the students that the model represents the Atlantic Ocean (west-east).

6. A few minutes should be granted for the students to get familiar with the compass and model itself.

7. Students start the activity. Be sure that the students place the compass just in front of the letters and numbers written on the model.

Answer to questions:

1. There are two arrows pointing toward the model and two arrows pointing away from the model on each side of the ridge.

2. The magnetic pattern is the same on each side of the ridge.
B. Slides and Discussion:

1. Distribute the questions to be answered while the slides are being shown.

2. Start the slide presentation. The teacher should relate very closely the slide presentation to the activity that the students just finished. Time should be allowed to create interaction among the students.

3. Students will need to refer to their tapes from the activity. Be sure they have them available.

4. The teacher should collect the student's guides.

C. Evaluation: Be sure students realize that student's guides will be evaluated.
PALEOMAGNETISM
(Student's Guide)

Objectives: Students will understand that fossil magnetism has been used as evidence of sea-floor spreading.

Students will be able to determine magnetic orientation of "rocks" making up the sea-floor.

Materials: Plaster model of the sea-floor.
Compass
Adding machine tape.

Procedure: 1. Observe the plaster model of the sea-floor. Identify the major features.

Rocks form the bottom of the sea. We are interested in the rocks found at locations A, B, C, D, 6, 4, 8, and 2.

2. Place a length of adding machine tape along the side of the model and mark the letters and numbers on it, so that they match those on the model.

3. Observe what happens when you bring the compass close to each of the locations.

4. Record at each position, the direction of the compass needle. Use an arrow.

5. Mark on the tape the location of the Mid-Atlantic ridge, and the other sea-floor features.

Questions: 1. What happens to the magnetic pattern as you go away from the ridge, Is this true for both sides?

__________________________________________________________________________

__________________________________________________________________________

2. How does the magnetic pattern on the left side of the ridge compare to the pattern on the right side of the ridge.

__________________________________________________________________________
PALEOMAGNETISM
(Transcript)

In this part of the study, we will consider some of the characteristics of the sea floor as well as the magnetic properties of rocks making up the ocean basins.

For many centuries men thought that the sea floor was a flat featureless surface in which all kind of monsters lived.

With the aid of "sonar" techniques, scientists have been able to determine the characteristics of the sea floor.

Sound waves are sent from a ship, the waves hit the rocks and are reflected back to the ship. Just like a player would hit a tennis ball against a wall and it will be reflected back to the player. A device called a receiver would measure the time that the sound wave spent going down and back. Since we know the velocity of the sound wave one can calculate the distance at which the rock is beneath the surface.

In this way, scientists have determined the depth of the features forming the sea floor. They realized that the sea floor is a zone of great relief in which mountains, valleys and ridges are quite common.

Perhaps the most striking feature found on the sea floor is a long mountain chain connected throughout all the oceans and usually in the middle of the ocean. This feature is called the "Mid -oceanic Ridge".

Your plaster model represents how the Atlantic Ocean floor would look from west to east.

Let's consider the magnetic properties of rocks.

For many years, man has known that a compass needle points toward the North. But... why is a compass needle attracted or deflected by the North Pole?

The earth can be considered as a huge magnet, and as any magnet, it has two poles- The North and South magnetic poles, which by the way, are not exactly the same as the North and South geographic poles.

The compass needle is attracted by the North magnetic pole. The part of the needle pointing toward the North magnetic pole is called the North seeking pole of the compass.

When lava or hot molten rocks are extruded by volcanoes, tiny little crystals forming the minerals begin to cool down and eventually will form a hard rock called basalt. Before the mineral crystallize, they become oriented in the direction of the earth's magnetic field present at that time.
In other words, the minerals would behave as compass needles, and would point toward the North magnetic pole.

The study of the magnetic properties of rocks formed millions of years ago is called paleomagnetism.

Suppose that a scientist has collected a rock from a specific location. In the laboratory and with the aid of very sensitive instruments he can determine the magnetic orientation that the rock had where it formed.

It has been observed that some rocks show a magnetic orientation which does not point toward the current North magnetic pole.

Scientists have concluded that this evidence supports the idea that the rocks have moved with respect to the North magnetic pole. In other words, drifting of continents has taken place.

Scientists studying rocks from the bottom of the sea have determined that some rocks show a magnetic orientation which is pointing toward the North magnetic pole, but other rocks on each side of the ridge show magnetic orientations which are completely opposite to the current North magnetic pole. This orientation has been called "polarity reversal"

Did you find any reversals while determining the magnetic orientation of the rocks in your model?

Did you find any pattern?

Scientists determining the age of the sediments across the ridge have observed that closer to the ridge are the youngest and those farther away from the ridge are the oldest.

You have seen that rocks on opposite sides of the ridge, and at equal distances from the ridge have the same magnetic orientation. Thus, they were formed at the ridge at the same time, acquired the magnetic orientation existing at that time, progressively they have been moving apart forming the sea floor.

In our next topic we will study how the sea floor has been spreading, and its implications in terms of crustal evolution.
PALEOMAGNETISM. Slide Discussion
(Student's Guide)

Answer the following questions:

1. How do scientists determine the depth of features found on the sea floor?

2. What is the mid-oceanic ridge?

3. What is paleomagnetism?

4. Explain briefly how rocks acquire magnetic orientation.

5. How many reversals did you find while working in the model of the Atlantic sea-floor?

6. Did you find any pattern on either side of the model? (Explain)

7. How would you explain the fact that rocks at position 6 and D have the same magnetic orientation and the same age?

8. Are there more rocks having the same magnetic orientation and the same age? Yes____ No____
9. If your answer was yes. What are these?

10. List from youngest to oldest the rocks studied in your model.

11. Explain how the rocks making up the sea floor model ended up in the positions in which they are right now.
VOLCANOES

(Teacher's Guide)

Objectives: Students should be able to associate volcanoes to production of new crust.

Students should be able to consider volcanoes as consequence of dynamic processes undergoing in the earth's interior.

Materials: This Restless Earth, Part II: A Study of Volcanoes and Continental Drift.

Directions: 1. This tape deals with geologic activities taking place in Iceland.

2. A classification of volcanoes and lavas is considered in this part. Students should not be concerned with such classification nor names and specific geologic terms used in the narration.

3. Distribute the student's guides. Questions should be answered while students are listening to the tape.

4. Emphasis should be placed on:
   A. Volcanoes as a way of production of new crustal material.
   B. Formation of ridges.
   C. Rift valleys.
   D. Geysers, hot springs, and volcanoes as indicators of the activity within the earth.

Answer to Questions:

1. The earth's interior must be a place in which temperatures are extremely high. High enough to melt rocks causing volcanic activity. Yet the mantle of the earth is solid.

   Ground water can be heated by contact with hot underground rocks. As it is heated, it may boil and when enough pressure builds up, a geyser erupts.

2. The thingvellir Valley. It was formed as a result of spreading of basalt. The basalt fractured and split. As the walls spread, material welled up into the center of the Thingvellir Valley.

3. Molten material rises up at the ridges, solidifies and moves laterally. This process is constantly going on.
VOLCANOES
(Student's Guide)

Objectives: Students should be able to associate volcanoes to production of new crust.

Students should be able to consider volcanoes as consequence of dynamic processes taking place in the earth's interior.

Materials: This restless Earth: A Study of Volcanoes and Continental Drift.

Questions: When you have listened to the tape, answer the following questions:

1. Based upon the nature of volcanoes, hot springs, and geysers, what can we conclude about the earth's interior?

2. What evidence has geologists found in Iceland that makes them believe in sea floor spreading? Explain _________

3. Explain how new crustal material seems to form along the ridges (Iceland). ________________________


CONVECTION CELLS
(Teacher's Guide)

A. Activity

Objectives: Students should be able to sketch the circulation pattern of a convection cell.

Students should be able to relate convection cells to sea-floor spreading and continental drift.

Materials: Beaker, 500 ml
Ringstand
Candle
Pepper
Potassium Permanganate

Directions:
1. Pre-laboratory discussion.
   What force or mechanism is responsible for the spreading of the sea floor?

   Why is the Thingvellir Valley still spreading apart?

   In this part of our unit, we will study what scientists currently believe causes the drifting of the continents or the spreading of the sea floor.

2. Distribute the student's guide.

3. Read the objectives.

4. Provide equipment for laboratory groups of three or four students each.

5. Supervise students carefully.

6. Post-laboratory.
   Special attention should be given to density, heat and their relationship.
   Similarly the students should have a clear understanding of:
   a. production of "new" crust is happening where convection cells are rising up.

   b. destruction of crustal material is happening at trenches, where convection cells are moving down.
Teacher's Guide. Continuation.

Answer to Questions:

1. The permanganate after a few minutes started to rise up, it reached the surface and moved laterally spreading the pepper.

2. 

3. A source of energy and a fluid.

4. When the potassium permanganate is heated its density decreases, thus it rises up.

5. "...if a rock is heated it expands and its density decreases, the mantle rock can rise upward (in a plastic fashion like red hot steel). The mantle cools as it moves horizontally, as it cools, its density increases until it eventually becomes heavy enough to sink down through the surrounding mantle, forming the downward limb of the convection cell..." (Wyllie, 1976, p.229).

6. A convection cell reaching the surface would move in opposite directions, thus spreading takes place.

7. A rift valley.

8. Crust is bent. Destruction of crustal material is accomplished. Trenches and subduction zones are formed.

B. Sile Discussion:

1. Distribute student's guide.

2. Start presentation.

3. Have students complete questions on student's guides while observing the slides.
CONVECTION CELLS
(Student's Guide)

Objectives: Students should be able to sketch the circulation pattern of a convection cell

Students should be able to relate convection cells to seafloor spreading and continental drift.

Materials: Beaker (500 ml.)
Ringstand
Candle
Pepper
Potassium Permanganate

Procedure: In this activity we will observe how a convection cell can be formed, and what its characteristics are.

1. In a 500 ml. beaker, add water up to the 400 ml. mark.

2. Place a small grain of potassium permanganate in the beaker.

3. Place the beaker on a ringstand.

4. Position the beaker so that it is about one inch above the flame of the candle. The candle flame must be directly below the grain of potassium permanganate.

5. Sprinkle a small amount of pepper in the water.

6. Now light the candle and observe what happens in the water to the pepper.

7. After 2-3 minutes, blow out the candle and clean up your area.

Questions: 1. Explain briefly what has happened.

2. Sketch the pattern followed by the potassium permanganate.

3. What is necessary for convection currents to form?
4. Explain how density and heat are related in this experiment.

5. How could convection cells occur in the earth's interior? Explain.

6. How could a convection cell mechanism cause sea floor spreading?

7. What geologic feature would you find in places where convection cells are rising and bringing hot magma?

8. What would happen in places where convection cells are moving down?
CONVECTION CELLS

(Transcript)

In general the continental drift theory has been widely accepted during the past 20 years. However, one of the weaknesses of this theory was the lack of a satisfactory mechanism able to account for the movement of the continents.

Scientists, aware of this weakness, proposed a convection cell mechanism which could explain adequately the motion of the continents, formation of ridges and trenches as well as the geologic activity around the globe.

You have just drawn a sketch of the path followed by the convection currents formed in the water-potassium permanganate system.

Scientists believe that convection cells are the forces moving segments of crust which rest on them. These segments are called PLATES.

Convection cells move plates, thus, continents riding on plates move and ocean basins may widen.

Do you remember what happened to the Thingvellir Valley? How can a convection cell be responsible for the spreading of the valley?

Convection cells do not just move plates apart; there are places on the earth's surface in which convection cells descend. These areas are called trenches or subduction zones. These areas are characterized by great geologic activity. Scientists believe that destruction of crustal material is occurring at trenches. Some of the subducted crust melts due to higher temperatures and pressures, and may eventually be extruded as lava from volcanoes.
CONVECTION CELLS - Slide Discussion

(Student's Guide)

Answer the following questions.

1. What are plates?

2. Explain how an ocean basin can be widened by a convection cell?

3. What are trenches?

4. How do trenches form?

5. What kind of geologic activity is present at the trenches?

6. What can happen to the crust at the trenches?
EARTHQUAKES
(Teacher's Guide)

A. Activity

Objective: Students should be able to relate earthquakes to plate boundaries.

Materials: Map showing earthquake activity from 1961 to 1967.

Directions: 1. Provide a brief introduction. Where do earthquakes occur? Scientists have plotted areas in which earthquakes have occurred. Soon, they realized that earthquakes do not occurred randomly all over the world but in some specific belts.

The map that we are going to study is the result of seven years of recording and plotting of earthquake activity around the world.

2. Distribute the student's guide, and the map. (one for each student) Read the objective.

3. Give a brief explanation of the way the lines ought to be drawn. Make clear that the lines do not necessarily pass through all the points plotted on the map. "We are looking for the best line fitting all the points."

Answer to Questions:

1. Six major areas should be outlined, and some smaller ones. Observe Central America.

2. Plates

3. Plate boundaries are very active.

4. Interaction of two plates moving in opposite direction.

5. A convection cell is moving crustal material down, forming a trench (destruction of crust).

Since the students have already studied about convection cells, questions 4 and 5 should be answered as completely and precisely as possible.

When the students have finished this activity, the teacher should collect the answers.
B. Slide presentation:

1. After the students have finished the activity, distribute the questions to be answered during the slide presentation.

2. Additional comments as well as interaction among students are welcomed.
Objective: Students should be able to relate earthquakes to plate boundaries.

Materials: Map showing earthquake activity from 1961 to 1967.

Procedure: Earthquakes and volcanoes have been considered the most devastating of earth phenomena; they originate several miles below the earth's crust. However, their effects on shaping the land surface are quite obvious.

In order to learn more about this phenomena, scientists determine the locations in which they occur.

Your teacher will give you a map locating earthquake activity from 1961 to 1967.

With a pencil, draw lines through zones of significant earthquake activity.

Questions:
1. How many areas did you outline? ____________________________

2. What do geologists call these areas? ________________________

3. What can you conclude about the geologic activity along the plate boundaries? _________________________________

4. What do you think causes the intense earthquake activity along the west coast of South America? ________________________

5. In which direction do convection cells move along the west coast of South America? ______________________________
DISTRIBUTION OF ALL EARTHQUAKE EPICENTERS RECORDED BY U. S. COAST AND GEODETIC SURVEY, 1961 to 1967. (from Barazangi and J. Dorman)
As you have seen in your map, earthquakes are distributed around the world.

Earthquakes mark the boundaries of plates. Scientists have identified six major plates and several small ones.

How many plates did you identified?

You can observe that there are some areas in which earthquake and volcanic activity is more frequent. In other words, these areas represent zones of greater interaction between plates.

Now we will study the kinds of interactions going on at plate boundaries.

1. The collision of two landmasses would trigger the formation of mountains. Do you remember what mountains were formed as a result of the collision of India with Asia? The movement of the plates interacting can be represented by two arrows pointing toward each other.

2. On the ridges, we know that the movement is quite different. How would you represent the movement of plates at the ridges?

well... convection cells are rising up at the ridges and moving away from each other. Thus, plates must be moving away from each other.

3. The third kind of movement can be studied in a subduction zone in which material is being overridden by a plate moving in opposite directions.

How would you represent this kind of interaction?

This pattern is typical of the west coast of South America in which a great deal of geologic activity is taking place.

Explain how the Andes formed.
EARTHQUAKES—Slide Discussion.
(Student's Guide)

Answer the following Questions:

1. What are plates?

2. What kind of geologic activity mark the plate's boundaries?

3. The collision of two landmasses would trigger the formation of mountains. Do you remember what mountains were formed as a result of the collision of India with Asia?

4. With the aid of two arrows, represent the movement of plates at the ridges.

5. How would you represent the movement of plates in a subduction zone?

6. Explain how the Andes formed?
APPENDIX B

ACHIEVEMENT AND ATTITUDE POOLS
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Scientists learned the most about the ocean floor topography from
   (A) photographs of the floor taken by earth satellites.
   (B) photographs of the floor taken by submarine.
   (C) sound waves reflected back to ships.
   (D) dropping weighted lines over the side of the ship and noting the depth at which the line stopped.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Easy A: B: C: D: E Hard

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Information from the "trapped" magnetism in rocks indicates that the ocean floor
   (A) is moving at a rate of about 2-10 centimeters per year.
   (B) is moving at a rate of about 2-10 meters per year.
   (C) is stable and does not move.
   (D) oscillates, that is, moves back and forth.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Worthless A: B: C: D: E Valuable
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Which of the following types of information can be used to support the idea that the continents at one time were together and have since drifted to the present positions?

   (A) The apparent wandering of the north magnetic pole over the past 400 million years.

   (B) The shape of the mare areas of the moon.

   (C) The thick ice covering of Antarctica.

   (D) Variations in ocean surface temperatures over the past 200,000 years.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Understandable A : B : C : D : E Mysterious

   Busy A : B : C : D : E Lazy
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Igneous rock as it cools and hardens "traps" the direction of the north magnetic pole within the hardening rock. When studying this "trapped" magnetism scientists have found that

(A) the direction of the magnetic poles has changed.

(B) magnetic poles did not exist until about 100 million years ago.

(C) the direction of the magnetic poles has always been what it is today.

(D) the earth's geographic poles have changed in the past.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Fast A : B : C : D : E Slow

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Attempts have been made to put North America and Europe into a single continent. Iceland which is a part of the Mid-Atlantic Ridge never fits.

   (A) This fact cannot be settled by the crustal evolution theory.

   (B) By changing the positions of Europe and North America, Iceland could be made to fit.

   (C) This is not a problem since Iceland did not originate until after North America separated from Europe.

   (D) Iceland was probably a part of Eastern Africa and therefore it is not necessary to try to fit it into a reconstruction of a combined North America and Europe.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Strong A : B : C : D : E Weak
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. The coastlines of western Africa and eastern South America appear to fit together. This information
   (A) proves continental drift. At one time the two continents must have been part of the same piece of crust.
   (B) supports continental drift. The two continents could have been parts of the same piece of crust.
   (C) contradicts continental drift. Other continents cannot be fitted together in a similar manner.
   (D) has no bearing on continental drift. There can be many other reasons for the apparent fit of the two coastlines.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Irritating A : B : C : D : E Pleasant

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. You could piece together cut-outs of continents into a single landmass much as you might take pieces of a puzzle and put them together. The fact that the various continents would more or less fit together
   (A) shows that at one time they were a single landmass.
   (B) shows that at one time they could have been a single landmass.
   (C) shows that they were never parts of the same landmass since the fits are not perfect.
   (D) means little about a single landmass.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Busy A : B : C : D : E Lazy
Day_____________ Name__________________________ Number________________

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Which of the following arguments might be used to support the concept of continental drift?
   (A) There are similar rocks in Africa and South America.
   (B) The continents of Africa and Europe fit together.
   (C) There is evidence of glaciers being in South America and Africa at the same time.
   (D) All of the above would support the concept.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Valuable A : B : C : D : E Worthless

Day_____________ Name__________________________ Number________________

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Which of the following information can be used to support continental drift?
   (A) Land fossils found in South America, Antarctica, Africa, and elsewhere.
   (B) Very old mountain ranges found in eastern South America and western Africa.
   (C) Changes in the energy output of the sun as indicated by sunspots.
   (D) Both A and B.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Strange A : B : C : D : E Familiar
1. The presence of very similar fossil remains in South Africa and Antarctica can be best explained by
   (A) polar drift.
   (B) continental drift.
   (C) glaciation.
   (D) mid-oceanic ridges.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Worthless A  B  C  D  E Valuable
Answer the following two questions on the separate answer sheet stapled onto your folder.

Use the following diagram to answer this question.

1. If you found rocks of the same age at two of the following locations, which two locations would be of the greatest aid in proving continental drift?

   (A) 14,15
   (B) 10,11
   (C) 3,2
   (D) 8,9
   (E) 12,14

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Mysterious: A: B: C: D: E: Understandable
Answer the following two questions on the separate answer sheet stapled onto your folder.

Use the following world map to answer this question.

1. At which of the following locations are the youngest rocks?
   (A) 1 and 5.
   (B) 2 and 4.
   (C) 1 and 3.
   (D) 2 and 5.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Strange A : B : C : D : E Familiar
Answer the following two questions on the separate answer sheet stapled onto your folder.

Use the following world map to answer this question.

1. At which of the following locations are the oldest rocks?
   (A) 2 and 3.
   (B) 3 and 4.
   (C) 2 and 4.
   (D) 3 and 5.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Irritating A : B : C : D : E Pleasant
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Studies to determine the age of rocks in the Atlantic Ocean have revealed that the ages of sediments are
   (A) older as you go from Africa to South America.
   (B) younger as you go from Africa to South America.
   (C) younger as you go away from the mid-Atlantic ridge.
   (D) older as you go away from the mid-Atlantic ridge.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Familiar: A : B : C : D : E Strange

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Geologists believe Antarctica, South America, Africa, India, and Australia were connected in ancient times. This belief is supported by
   (A) the study of present-day animal life.
   (B) satellite photographs.
   (C) the fossil record of each continent
   (D) the geographic location of the continents.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Success: A : B : C : D : E Failure
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Which one would be the BEST evidence that continents 1 and 2 were once a single super-continent?

   (A) 1 and 2 look like they could fit together.

   (B) 1 and 2 look like they could fit together and their rock units have similar ages.

   (C) The rock units in continent 1 are older than the rock units on continent 2.

   (D) The rock units on continent 1 are the same ages as the rock units on continent 2.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Week: A: B: C: D: E: Strong
1. Which one of the following numbers indicates the correct sequence of events?

(A) 1, 2, 3, 4
(B) 4, 2, 3, 1
(C) 2, 3, 1, 4
(D) 2, 4, 3, 1
(E) 4, 3, 1, 2

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

Failure: A : B : C : D : E Success
Answer the following two questions on the separate answer sheet stapled onto your folder.

Use the diagram below to answer this question.

1. Which drawing(s) indicate former positions of the continents?
   (A) 1
   (B) 2
   (C) 3
   (D) 4
   (E) 2 and 4

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Weak: A : B : C : D : E Strong
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Paleomagnetic data indicates that the Atlantic Ocean
   (A) Has never changed its size.
   (B) Has gotten bigger only in the past thousand years.
   (C) Has gotten bigger over the past several million years.
   (D) Is getting smaller.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Lazy  A  :  B  :  C  :  D  :  E  Busy

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Which statement about North America is probably true?
   (A) It has remained in its present position for a long time.
   (B) It is moving eastward.
   (C) It is moving westward.
   (D) It is gradually rising out of the mantle.
   (E) It is gradually sinking into the mantle.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Success  A  :  B  :  C  :  D  :  E  Failure
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Which of the following is (are) true statement(s)?
   (A) The age of the sediments decreases as you approach the ridge.
   (B) Convection currents move plates which rest on them.
   (C) Earthquakes and volcanoes occur at plate boundaries.
   (D) All of the above.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Boring: A: B: C: D: E: Exciting

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. If two continents collide what could possibly happen?
   (A) A trench may be formed.
   (B) An ocean ridge may be created.
   (C) Mountains may form.
   (D) Volcanoes may form.
   (E) None of the above.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Fast: A: B: C: D: E Slow
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. There is a great deal of volcanic and earthquake activity in the Himalayas and Tibetan plateau. This is because
   (A) Two plates are colliding.
   (B) Two plates are separating.
   (C) Two plates are sliding past each other.
   (D) It is in the cancer of a continent.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Failure A: B: C: D: E Success

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. According to the theory of plate tectonics, the downward movement of crustal plates into the mantle creates
   (A) mid-oceanic ridges.
   (B) continental shelves.
   (C) sea-floor trenches.
   (D) continental slopes.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   More A: B: C: D: E Less
Answer the following two questions on the separate answer sheet stapled onto your folder.

Use the following diagram to answer this question.

1. Which one of the following statements is true?
   (A) New crust may occur at position 8.
   (B) Crust may be destroyed at position 8.
   (C) There will be no change in crust at position 8.
   (D) None of the above are true.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

    Pleasant A: B: C: D: E: Irritating
1. At which one of the following locations would you expect major earthquake activity?

(A) 4
(B) 11
(C) 7
(D) 2
(E) 13

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

Fast  A: B:  C:  D:  E:  Slow
Answer the following two questions on the separate answer sheet stapled onto your folder.

Use the following diagram to answer this question.

1. At which location might you expect mountains to be formed?
   (A) 11
   (B) 9
   (C) 7
   (D) 6
   (E) 5

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Confusing: A: B: C: D: E: Clear
Answer the following two questions on the separate answer sheet stapled onto your folder.

Use the following diagram to answer this question.

1. At which location might you expect mountains to be formed?

(A) 7
(B) 4
(C) 14
(D) 5
(E) 2

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

Mysterious A: B: C: D: E: Understandable
1. At which location would you expect volcanic activity?
   (A) 1
   (B) 2
   (C) 3
   (D) 7
   (E) 8

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Pleasant A : B : C : D : E Irritating
1. At which location would you expect volcanic activity?

(A) 7  
(B) 8  
(C) 2  
(D) 6  
(E) 1  

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

Weak A : B : C : D : E Strong
Answer the following two questions on the separate answer sheet stapled onto your folder.

Use the following diagram to answer this question.

1. At which location would you expect earthquakes?
   (A) 1
   (B) 2
   (C) 5
   (D) 7
   (E) 8

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Busy A : B : C : D : E Lazy
Answer the following two questions on the separate answer sheet stapled onto your folder.

Use the following diagram to answer this question.

1. At which location would you expect earthquakes?
   - (A) 1
   - (B) 2
   - (C) 3
   - (D) 7
   - (E) 8

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Confusing : B : C : D : E Clear
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Which one of the following statements is correct?
   (A) New crust is formed at the ocean ridges.
   (B) All new continental rock comes from volcanoes.
   (C) All ocean basin rock is from eroded continents.
   (D) Very young rocks can occur anywhere on the crust.
   (E) None of the above.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Worthless A : B : C : D : E Valuable

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Crust farther away from the mid-oceanic ridge is
   (A) older than crust closer to the ridge.
   (B) becomes more magnetized.
   (C) does not show magnetic properties.
   (D) is overlain by the mantle.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Less A : B : C : D : E More
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Mid-ocean ridges are formed by
   (A) magma rising from the mantle.
   (B) collision of two plates.
   (C) convective currents moving down.
   (D) All of the above.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Slow A: B: C: D: E Fast
Answer the following two questions on the separate answer sheet stapled onto your folder.

Use the following diagram to answer this question.

1. Which one of the following statements is FALSE?
   (A) Continent M is moving West.
   (B) A trench is formed at position 3.
   (C) New material is produced along the ridge.
   (D) Rocks along the ridge are older than rocks at position 7.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Clear: A   B   C   D   E Confusing
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Which one of the following statements is true about the Himalayas?
   (A) They were formed millions of years before India collided with Asia.
   (B) Sedimentary rocks accumulated for millions of years forming the Himalayas.
   (C) The Himalayas were formed as a result of the collision of India.
   (D) The Himalayas were formed when India was closer to the South Pole.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Exciting A : B : C : D : E Boring

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Which one of these areas has very few earthquakes?
   (A) the east coast of North America
   (B) the mid-Atlantic ridge
   (C) the western edge of the Pacific Ocean
   (D) the west coast of North America and South America

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Strong A : B : C : D : E Weak
1. Where the ocean floor is moving down and under a continent, you would find
   (A) barrier islands.
   (B) coastal plains.
   (C) new mountains.
   (D) all three of these features.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Strange A : B : C : D : E Familiar

1. A world map with the locations of hundreds of earthquakes would show that earthquakes
   (A) occur in random patterns, no area has many more earthquakes than another.
   (B) occur along long narrow zones.
   (C) do not occur near ocean trenches or ridges.
   (D) occur in small separate clumps far from each other.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Irritating A : B : C : D : E Pleasant
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Which one of the following is an active coast?
   (A) West coast of South America.
   (B) North coast of Alaska.
   (C) North coast of Denmark and Germany
   (D) Gulf of Mexico.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   
   College A: B: C: D: E: More

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. The Himalayas are located on the border between Asia and India. This location is due to
   (A) the rotation of the earth.
   (B) the fossil record.
   (C) plate collisions.
   (D) geological subduction.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   
   Valuable A: B: C: D: E: Worthless
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Volcanoes are located
   (A) only in the oceanic trenches.
   (B) on the edges of continents.
   (C) only on the oceanic ridges.
   (D) near plate boundaries.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Exciting A : B : C : D : E Boring

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Which side of the United States is more active?
   (A) North
   (B) South
   (C) East
   (D) West

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Clear A : B : C : D : E Confusing
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. The presence of the mid-Atlantic ridge across Iceland suggests that Iceland
   (A) is sinking.
   (B) is growing larger.
   (C) was once part of Europe.
   (D) was once part of Greenland.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Pleasant A : B : C : D : E Irritating
Answer the following two questions on the separate answer sheet stapled onto your folder.

Use the following diagram to answer this question.

1. From the information above you could conclude that
   (A) Continent P is moving East.
   (B) Continent M is moving East.
   (C) Continent T is moving South.
   (D) Continent M is moving West.
   (E) Both A and D are correct.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Understandable A : B : C : D : E Mysterious
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. The idea that the earth's crust is composed of large pieces, along the borders of which most modern geologic activity (earthquakes, volcanoes) occurs, is called

   (A) plate tectonics.
   (B) evolution.
   (C) paleomagnetism.
   (D) convection.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Familiar A : B : C : D : E Strange
Answer the following two questions on the separate answer sheet stapled onto your folder.

Use the diagram below to answer this question.

1. The continents are arranged today as indicated by drawing(s)
   
   (A) 3  (D) 4  
   (B) 1  (E) 1 and 2  
   (C) 2  

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS.

   Valuable A: B: C: D: E Worthless
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Crustal plates are believed to be moved by
   (A) convection currents.
   (B) forces caused by the rotation of the earth.
   (C) tidal forces caused by the sun and moon.
   (D) magnetic reversals.
   (E) a combination of B and C.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Slow: A; B; C; D; E Fast

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. If something is heated, it will become less dense. What would happen if some rock in the mantle were heated? It would
   (A) spread laterally and remain at the same depth.
   (B) remain in the same position.
   (C) sink toward the center of the earth.
   (D) rise toward the crust.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Clear: A; B; C; D; E Confusing
Day____________ Name________________________________________
Number________________

Answer the following questions on the separate answer sheet stapled onto your folder.

1. Plates are thought to move because of

   (A) warm mantle rock rising.
   (B) cool mantle rock rising.
   (C) the effect of wind upon the surface.
   (D) drag due to the rotation of the earth.

2. Select the letter that best describes how you feel about TODAY'S
   SCIENCE CLASS

   Mysterious A : B : C : D : E Understandable

Day____________ Name________________________________________
Number________________

Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Continents on opposite sides of an ocean basin separate because convection currents.

   (A) rise at ocean ridges and move outward.
   (B) rise at ocean ridges and move outward on one side and inward on the other side.
   (C) move parallel to ocean ridges.
   (D) move inward and sink at ocean ridges.

2. Select the letter that best describes how you feel about TODAY'S
   SCIENCE CLASS

   Lazy A : B : C : D : E Busy
Answer the following two questions on the separate answer sheet stapled onto your folder.

For this question use the diagram below which represents a portion of the earth's crust and underlying mantle. The arrows represent convection currents in the mantle.

1. In the above drawing suppose positions V and Y are ocean basins.
   (A) both V and Y basins will get smaller.
   (B) both V and Y basins will get bigger.
   (C) both V and Y basins will remain the same.
   (D) basin V will get smaller while basin Y will get bigger.
   (E) basin V will get bigger while basin Y will get smaller.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   More A : B : C : D : E Less
Answer the following two questions on the separate answer sheet stapled onto your folder.

For this question use the diagram below which represents a portion of the earth's crust and underlying mantle. The arrows represent convection currents in the mantle.

1. Using the drawing above, which statement is true?
   (A) Rocks at 3 and 4 have the same density.
   (B) Rocks at 4 and 6 have the same density.
   (C) Rocks at 1 and 4 have the same density.
   (D) Rocks at 2 and 7 have the same density.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Boring A : B : C : D : F Exciting
Answer the following two questions on the separate answer sheet stapled onto your folder.

For this question use the diagram below which represents a portion of the earth's crust and underlying mantle. The arrows represent convection currents in the mantle.

1. Using the drawing above, which statement would be true?
   (A) Plates X, T and Z do not move.
   (B) Plates X and Z will collide.
   (C) Plates T and X will collide.
   (D) Plates X, T and Z will move back and forth.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Less A: B: C: D: E More
Answer the following two questions on the separate answer sheet stapled onto your folder.

For this question use the diagram below which represents a portion of the earth's crust and underlying mantle. The arrows represent convection currents in the mantle.

1. Using the drawing above, which statement would be true?
   (A) Plate Z is moving West while Plate T is moving East.
   (B) Plate Z is moving East while Plate X is moving East.
   (C) Plate Z is moving East while Plate T is moving West.
   (D) Plate Z is moving East while Plate T is moving East.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Lazy: A, B, C, D, E: Busy
Answer the following two questions on the separate answer sheet stapled onto your folder.

For this question use the diagram below which represents a portion of the earth’s crust and underlying mantle. The arrows represent convection currents in the mantle.

1. Using the drawing above, which statement would be true?
   
   (A) Plate X is moving East while Plate Z is moving West.
   
   (B) Plate T is moving East while Plate Z is moving West.
   
   (C) Plate X is moving West while Plate Z is moving East.
   
   (D) Plate T is moving West while Plate X is moving West.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Strong A:    B:    C:    D:    E Weak
Answer the following two questions on the separate answer sheet stapled onto your folder.

For this question use the diagram below which represents a portion of the earth's crust and underlying mantle. The arrows represent convection currents in the mantle.

1. The rocks at position 2 are less dense than the rocks at
   - (A) position 3.
   - (B) position 1.
   - (C) position 5.
   - (D) position 7.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   - Boring A: R: C: D: E: Exciting
Answer the following two questions on the separate answer sheet stapled onto your folder.

For this question use the diagram below which represents a portion of the earth's crust and underlying mantle. The arrows represent convection currents in the mantle.

1. Using the above drawing, which statement is true?
   
   (A) Rocks at 1, 3, and 7 have the same density.
   (B) Rocks at 2, 5, and 6 have the same density.
   (C) Rocks at 1, 6, and 7 have the same density.
   (D) Rocks at 3, 4, and 6 have the same density.

2. Select the letter that best describes how you feel about TODAY's SCIENCE CLASS

   Confusing_ _ _ _ _ : B : C : D : E Clear
Answer the following two questions on the separate answer sheet stapled onto your folder.

For this question use the diagram below which represents a portion of the earth's crust and underlying mantle. The arrows represent convection currents in the mantle.

1. Study the above diagram. Which one of the following statements would be true?
   (A) Plate T, Plate X, and Plate Z are moving West.
   (B) Plate T and Plate X are moving East while Plate Z is moving West.
   (C) Plate T and Plate Z are moving West while Plate X is moving East.
   (D) Plate T and Plate Z are moving East while Plate X is moving West.

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Exciting A : B : C : D : E Boring
Answer the following two questions on the separate answer sheet stapled onto your folder.

For this question use the diagram below which represents a portion of the earth's crust and underlying mantle. The arrows represent convection currents in the mantle.

1. At which one of the following positions would crust be destroyed?

   (A) T  
   (B) V  
   (C) X  
   (D) Y  
   (E) Z

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Success  A :  B :  C :  D :  E Failure
Answer the following two questions on the separate answer sheet stapled onto your folder.

For this question use the diagram below which represents a portion of the earth's crust and underlying mantle. The arrows represent convection currents in the mantle.

1. The production of new crust may be taking place at position
   (A) T
   (B) Y
   (C) X
   (D) Y
   (E) Z

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS
   Failure A :  B :  C :  D :  E  Success
Answer the following two questions on the separate answer sheet stapled onto your folder.

For this question use the diagram below which represents a portion of the earth's crust and underlying mantle. The arrows represent convection currents in the mantle.

1. At which one of the locations might the convection currents cause an ocean trench?
   
   (A) 1,6
   (B) 3,4
   (C) 2,7
   (D) 6,7
   (E) 5,8

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS.
   
   Slow A: B: C: D: E Fast
Answer the following two questions on the separate answer sheet stapled onto your folder.

1. Which combination of convection cells would you expect to find at a location where two plates are known to be moving toward each other?

   (A) 
   (B) 
   (C) 
   (D) 

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Familiar A : B : C : D : E Strange
Answer the following two questions on the separate answer sheet stapled onto your folder.

Use the diagram below to answer this question.

1. Which one of the following numbers may indicate future position of the continents?
   
   (A) 1  (D) 4  
   (B) 2  (E) 1 and 2  
   (C) 3

2. Select the letter that best describes how you feel about TODAY'S SCIENCE CLASS

   Understandable____:____:____:____:____ Mysterious
APPENDIX C

ANSWER SHEET AND PARAGRAPHS

USED DURING THE STUDY
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The following paragraph deals with some of the ideas that you have discussed in class. Read it carefully.

Deposits of coal result from the accumulation of vegetation in swamps and bags in which little sediment is deposited. Preservation of the vegetation occurs in swamp water which is saturated with decay products and is low in oxygen. Once buried in the swamp partially decomposed vegetable matter (peat) is converted to coal by slow chemical and physical changes in which compression, heat, and time are important factors. In the process of change oxygen, hydrogen, and water are released while carbon accumulates as a residual deposit.

Question:

1. Is coal a mineral? ______ Explain your answer ____________________

______________________________

______________________________

______________________________

Place this sheet back in your folder. Your teacher will collect it at the end of the period.

If you have any questions, be sure to ask them next time. Thanks.
The following paragraph deals with some of the ideas that you have discussed in class. Read it carefully.

How Are Mineral Deposits Found?

The finding of mineral deposits varies from the ridiculous to the ultrascientific. For example, one copper deposit in the Upper Peninsula of Michigan was found by a man searching for his lost pig, another by detailed geological and geophysical research. Many are found by luck coupled with keen observation and a knowledge of rocks and minerals. As a result of man's unending search for mineral wealth, most of the easily recognized deposits have been discovered—fewer of the more obscure deposits. Being obscure does not mean that the deposits are necessarily small, but that they do not have features which can be readily recognized by visual observation of surface rocks or surface materials.

Place this sheet back in your folder. Your teacher will collect it at the end of the period.

If you have any questions, be sure to ask them next time. Thanks.
The following paragraph deals with some of the ideas that you have discussed in class. Read it carefully.

Ohio's vast wealth of mineral sources is a significant contributor to the state's economy. Ohio is a major supplier of clay, limestone, dolomite, salt, sand, gravel and shale. Ohio ranks fifth in the nation in coal production. With mineral resources becoming increasingly important to the state's economy, and with competition for land becoming more intense, it is vital to Ohio's growth and development that we know the location of our mineral resources.

Questions:

1. In what part of the state of Ohio are most of the coal mines located?

2. What is the main mineral found around Columbus?

Place this sheet back in your folder. Your teacher will collect it at the end of the period.
The following paragraph deals with some of the ideas that you have discussed in class. Read it carefully.

Minerals are the building blocks of the earth's crust, and the raw materials for things of inorganic origin that are made and used by man. However, minerals are not studied for the sole purpose of determining whether a deposit may have economic value. Information gained from the study of minerals has shed light on the very origin of the earth.

Questions:

1. Name some minerals whose economic value is determined by their "beauty"?

Place this sheet back in your folder. Your teacher will collect it at the end of the period.
The following paragraph deals with some of the ideas that you have discussed in class. Read it carefully.

Continental Drift; The Great Debate.

The earth sciences have been shaped by a series of great controversies and a host of minor disputes. The arguments have been such as to give the impression that geologists enjoyed the excitement of the debate more than the prospect of getting together to define the terms of their disagreements in an effort to resolve a dispute. The debate of this century has been about continental drift.

Continental drift is an old idea, formulated originally to explain the striking parallelism of the Atlantic coasts. The idea of a mobile earth was familiar to geologists by 1900, but the concept of continental drift was not taken seriously until 1915.

Question

What evidence(s) are in favor of continental drift.

Place this sheet back in your folder. Your teacher will collect it at the end of the period.

Thanks.
The following paragraph deals with some of the ideas that you have discussed in class. Read it carefully.

Alfred Wegener: Drifter and Explorer.

Alfred Wegener is well known now for his advocacy of continental drift despite the severe criticisms from influential geologists and geophysicists, but he is less widely known for his other activities, which also involved adverse conditions. Wegener was one of the great arctic explorers. While he was a student in Berlin, earning a doctoral degree in astronomy, Wegener escaped to the mountains whenever possible to build up his endurance by climbing and skiing.

Wegener's first book, (The origin of Continents and Oceans) was published in 1915, and the fourth edition, revised, was published in 1929, the year that he lead a preliminary reconnaissance party onto the Greenland ice sheet.

Question.

What was Wegener's ideas about the continents?

Place this sheet back in your folder. Your teacher will collect it at the end of the period.
The following paragraph deals with some of the ideas that you have discussed in class. Read it carefully.

Echo Sounding

The old time-consuming system of determining ocean depth by the use of a weighted wire is not very accurate and has now been replaced by electronic methods. Figure 1 illustrates the principle involved in echo sounding. A transmitter sends a sound wave which is reflected back to the surface by the ocean bottom. A receiver picks up the reflected sound wave. By knowing the speed of the sound wave in the water and the time required for the sound to go down to the ocean floor and come back to the receiver at the surface, ocean depth can be calculated. A continuous record (echogram or bathogram) of the ocean floor profile can be made by a moving ship. The so-called fish-finder on board many commercial fishing vessels operates on the same principle except that the sound waves are bounced back from fish as well as from the bottom. In fact, some fish are so uniform in their schooling habits that they produce a false bottom known as a deep scattering layer.

Question:
Describe the bottom of the Atlantic Ocean.

Place this sheet back in your folder. Your teacher will collect it at the end of the period.
The following paragraph deals with some of the ideas that you have discussed in class. Read it carefully.

THE OCEAN RIDGES AND CONTINENTAL DRIFT.

Has the recent study of the ocean basins supplied any clues to continental drift? Some say yes; some say maybe. Most of the evidence comes from the North Atlantic Ocean basin. The most important of this is from the mid-ocean ridge. The scientists who have made most of the studies are at the Lamont Geophysical Laboratory. What have they discovered?

Dredge samples from the crest of the ridge have shown, that the rocks are recently extruded basalts. Core samples of the sediments show a peculiar situation. On the flanks of the ridge, the sediments are thin and recent. The farther east or west from the ridge that the samples are taken, the older are the bottom sediments. Not only are the bottom sediments older, but also the thickness of the sediment layer is greater.

Question:
Describe the mid-Atlantic ridge.

Place this sheet back in your folder. Your teacher will collect it at the end of the period.
The following paragraph deals with some of the ideas that you have discussed in class. Read it carefully.

Earthquake rocks southern Alaska

YAKUTAT, Alaska (UPI) — A strong earthquake rocked Alaska and part of Canada Wednesday, shaking buildings from Juneau to the Alaska oil pipeline terminal at Valdez. There were no reports of major damage or injuries.

The U.S. Geological Survey at Golden, Colo., said the quake measured 7.5 to 8 on the Richter scale.

The center of the quake was several hundred miles east of a 1964 Alaskan earthquake that had a Richter measurement of 8.5 and killed 114 people. The 1964 quake caused $400 to $500 million in damage to Anchorage alone.

The Richter scale is logarithmic and a 7.7 quake is one-eighth as strong as a quake that measures 8.5.

The quake, which hit at 11:27 a.m. Alaska time, 4:27 p.m. EST, was centered 100 miles northwest of Yakutat near 18,000-foot Mount St. Elias. It rattled homes of the some 200 residents of Yakutat, but a spokesman there reported no structural damage.

There was also no damage reported to the 800-mile pipeline that carries Alaska North Slope oil to the shipping terminus of Valdez. The quake was also felt in Whitehorse, Canada.

Precise measurements of the earthquake conflicted, but the closest reporting station, the Alaska Tsunami Warning Center at Palmer, Alaska, set it at 6.9 on the Richter scale after taking reference measurements from several Alaskan checkpoints.

The University of California Seismographic Station at Berkeley, Calif., measured the quake at 7.7.

The Pacific Tsunami Warning Center in Hawaii said the Alaska quake was not of sufficient magnitude to generate a Pacific-wide tsunami.

Question:

Explain the relationship between plate movements and the Alaskan earthquake.
The following paragraph deals with some of the ideas that you have discussed in class. Read it carefully.

The earth's crust consists of about six large plates, usually larger than individual continents; many smaller plates have also been postulated. These plates include both the continents and part of the ocean bottom. In other words, the boundaries between these plates are not the continent-ocean boundaries. Instead the boundaries between various crustal plates may be either the rises at which new crust is continuously forming, the trenches at which old crust is being destroyed, or major faults, where crustal plates slide past each other. The movement of these plates is thought to result from convective motions in the mantle. The edges of the plates are usually located by lines of frequent earthquakes, groups of volcanoes, or active mountain building.

Question:

What is the relationship between plate boundaries and geologic activity. (earthquakes, volcanoes)

Place this sheet back in your folder your teacher will collect it at the end of the period.

Thanks.
The following paragraph deals with some of the ideas that you have discussed in class. Read it carefully.

Earthquakes: An earthquake results from anything that causes the rocks of the earth's crust to vibrate. Most large earthquakes occur because two large masses of rock slip a little along a fault. When vibrations are produced as these masses of rocks (plates) rub against one another, we say an earthquake has occurred. No part of the earth is entirely free of earthquakes. Large areas of both the continents and the oceans experience occasional mild shakes that pass unnoticed. Earthquakes that we do notice are called sensible earthquakes. Sensible earthquakes almost always occur where the earth's crust is unstable, that is where mountains are growing or where volcanoes are active. This locates the most violent earthquakes around the perimeter of the Pacific Ocean, in the Mediterranean Sea, and eastward to the Himalaya mountains, and along the mid-ocean ridges.

Questions:

Explain why earthquakes or volcanoes do not occur in Ohio

Place this sheet back in your folder. Your teacher will collect it at the end of the period.
The following paragraph deals with some of the ideas that you have discussed in class. Read it carefully.

Resources from Seawater:

The Ocean constitutes the world's largest single source of raw materials. Many materials being produced commercially are replenished by rivers bringing new supplies into the oceans faster than man is extracting them. Despite the large number of substances occurring in seawater, only four have been economically extracted: Fresh water, Salt (NaCl), Bromine, and Magnesium. In 1968 the ocean was the source of 29 percent of the world's salt, 70 percent of its bromine, 61 percent of its magnesium metal, 6 percent of its magnesium compounds. These products, worth $400,000,000 were produced in about 60 countries.

Water is probably the ocean's most valuable potential resource. As the world population expands, coastal cities in arid regions will doubtlessly derive part or all of their water from the ocean. Man is trying to duplicate the natural water cycle, evaporating sea water to recover fresh water. The problem is to recover the fresh water at the location where it is to be used at the time it is needed.

Question:

What is the economic importance of the oceans?

Place this sheet back in your folder. Your teacher will collect it at the end of the period.

Thanks.
The following paragraph deals with some of the ideas that you have discussed in class. Read it carefully.

Distribution of Land and Water:

Of the total surface area of the earth, water occupies more than twice as much as land; more precisely, the earth is 71 percent water and 29 percent land. A glance at a globe or world map also shows that there is considerably more land in the northern hemisphere than in the southern.

97 percent of all water on earth is marine; that is, it is in oceans and seas. This leaves only 3 percent of all water, whether liquid, solid, or gas in other environments. Lakes, rivers, and ground water account for about 2 percent, snow and ice (glaciers), 1 percent, and atmospheric water, 0.00005 percent of the total.

In comparing size and shape of the major water bodies, we notice that each has its own features. Although the Atlantic and Indian Oceans are not much different in size, the shapes contrast. Even within the Atlantic, the configuration of the northern part is considerably different from that of the southern part.

Question:

Name the oceans bordering the East and West coast of North America.

Place this sheet back in your folder. Your teacher will collect it at the end of the period.
APPENDIX D

INTERVIEW SCHEDULE
INTERVIEW SCHEDULE

Name________________________

Testing Schedule___________

1. Do you like the science Class?       Yes  ____
                                               No  ____
                                         Not sure ____

2. Did you like the crustal evolution unit?
                                               Yes  ____
                                               No  ____
                                         Not sure ____

                        Explain.__________

3. What do you think of the questions (paragraphs) that you received during the last few weeks?
                                               I liked them____
                                               I did not like them____
                                               I am not sure____
                        Explain.______________

4. You know that some of your friends received questions (paragraphs) almost every day. What do you think about that procedure?
                                               It is O.K.____
                                               It is not fair____
                                               I do not care____

5. Did you really try to answer the questions to the best of your ability?
                                               Yes____       No ____  Explain.______________
APPENDIX E

ITEM ANALYSIS AND HOYT RELIABILITY MEASURES

OF THE ATTITUDE POOL
## Subject Indices

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## Summary Statistics

- Mean: 32.527
- Standard Deviation: 9.068
- Variance: 82.030
- Sum: 264
- Sum of squares: 92.210

### Warning

Sum of test scores and sum of item scores are not equal.

## Item Analysis

### Item Choice

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