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RELATIONSHIPS BETWEEN CONCRETE AND FORMAL INSTRUCTIONAL PROCEDURES AND CONTENT-ACHIEVEMENT, INTELLECTUAL DEVELOPMENT AND LEARNER I.Q.

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RELATIONSHIPS BETWEEN CONCRETE AND FORMAL INSTRUCTIONAL PROCEDURES AND CONTENT-ACHIEVEMENT, INTELLECTUAL DEVELOPMENT AND LEARNER I.Q.

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

BY

LIVINGSTON S. SCHNEIDER

Norman, Oklahoma

1977

RELATIONSHIPS BETWEEN CONCRETE AND FORMAL

INSTRUCTIONAL PROCEDURES

AND

CONTENT-ACHIEVEMENT, INTELLECTUAL

DEVELOPMENT AND LEARNER I.Q.

APPROVED BY

James M. Robertson

DISSERTATION COMMITTEE

DEDICATION

This study is dedicated to Livingston S. Schneider, Sr., my father and Grace L. Schneider, my mother. Their support and encouragement throughout my education has been especially valuable.

Deep gratitued is expressed to Dr. John W. Renner, my doctoral committee chairman for his tireless and indispensible assistance in designing the study, consultation and editing of the content material and content examinations, and advise on the reporting of the results of the study. Appreciation is also expressed to the members of my doctoral committee for their reviews of early drafts of the report and their critical suggestions for its improvement.

A word of thanks is given to the students who participated in this investigation. The instruction was an enjoyable, exciting and stimulating experience for the investigator.

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CHAPTER I

INTRODUCTION, STATEMENT OF THE PROBLEM AND HYPOTHESES

Introduction

During the decade of the 1960s, the Science Curriculum Improvement Study introduced a concept to science education which is best described as the learning cycle.[1] That cycle consists of three essential parts. First the learner is given all types of experience with objects, events and/or situations which will provide him the background necessary to allow him to understand a particular concept. That procedure is identified as exploration. The name of the concept is then provided to the learner by the teacher or the student himself identifies it. In the majority of cases the teacher will provide the identification of the concept. This latter procedure is called conceptual invention. After the concept has been invented for the learner the teacher provides additional activities which will allow the student to discover the broad applicability and usefulness of the newly-invented concept. That phase of the learning cycle is known as discovery. Exploration,

[1]For a more complete discussion of the learning cycle, see John W. Renner, Don G. Stafford and William B. Ragan, Teaching Science in the Elementary School, (New York: Harper and Row, 1973), pp. 105-114.

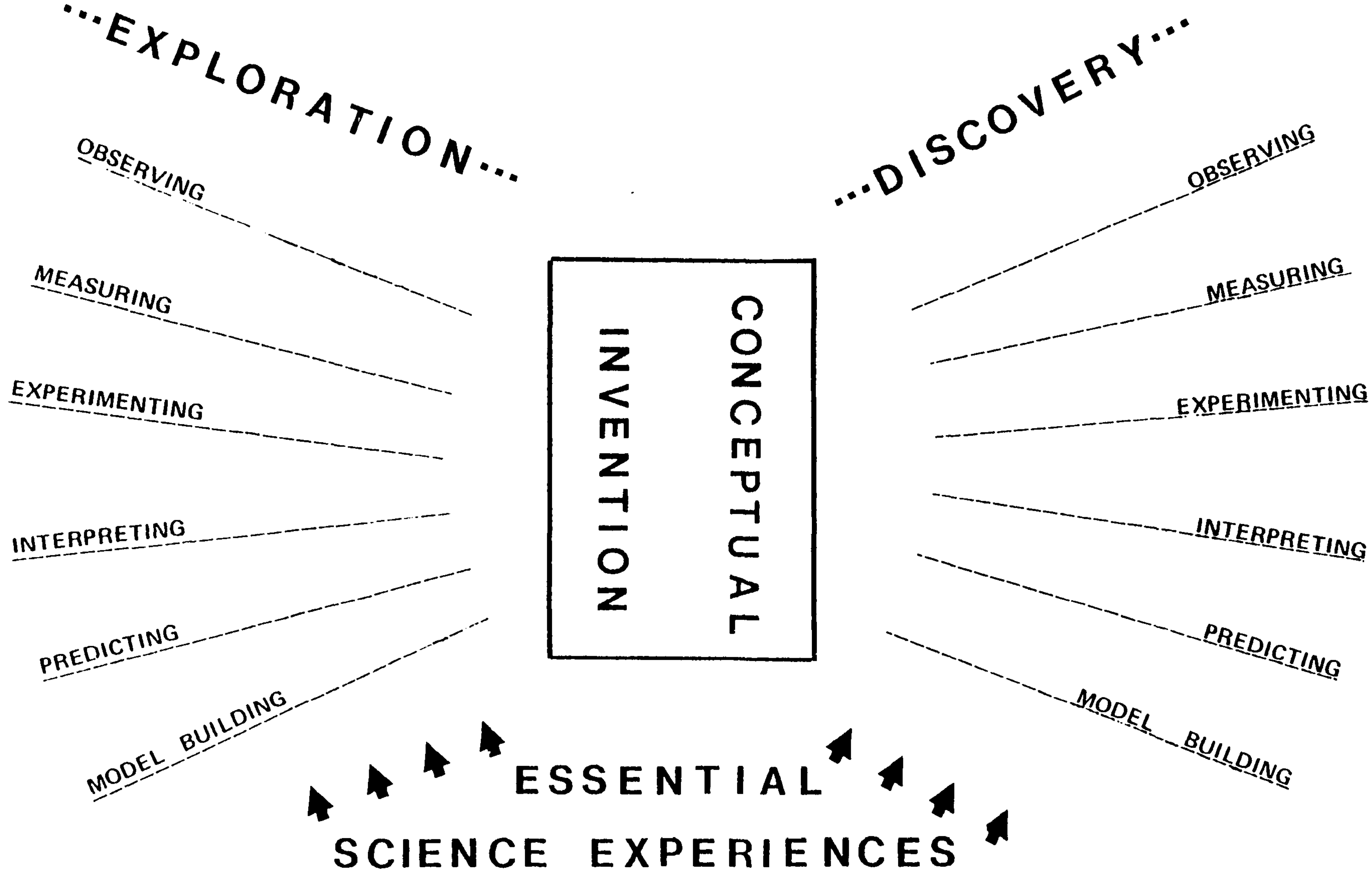
invention and discovery constitute the learning cycle. Figure 1-1 presents a graphic description of the learning cycle. A close examination of the learning cycle reveals that it is synonymous with inquiry. That examination also demonstrates that inquiry and discovery are not different labels for the same process as is frequently demonstrated in the press and much professional literature. The rise of inquiry may be thought of as <u>concrete instruction</u> and it includes the use of laboratory apparatus, social interaction and laboratory experience.

In contrast to concrete instruction is the traditional didactic, expository process of instruction utilized extensively whereby facts, ideas and concepts are presented, explained or expounded to the learner by the teacher with the purpose of leading the student through postulatory deductive reasoning systems. Concepts are defined through their position in the system; i.e., their relation to other concepts. This method may be thought of as <u>formal instruction</u> and utilizes lectures given by the teacher, demonstrations done by the teacher of concepts, pictures and diagrams of objects, situations and/or events and reading assignments carried out by the student.

Concrete and formal instruction represent fundamentally differing theory bases for education. Research is not available which tells whether or not a significant difference in the type and permanence of changes in student content-achievement and intellectual development result when concrete and formal instruction techniques are used with two groups of concrete operational students experiencing the same content.

FIGURE 1-1

THE LEARNING CYCLE



In addition data are not available which let conclusions be drawn about the impact of concrete and formal instruction on learner I.Q.

Statement of the Problem

The primary objective of this study was to investigate differences between concrete instruction and formal instruction on concrete operational learners.

Specifically, the relationships between the two instruction methodologies and content-achievement, intellectual development, learner I.Q. and retention of gains made in content-achievement, and intellectual development by ninth grade physical science students were investigated.

This study, then, sought to answer the following questions:

1. What are the relationships between concrete instruction and formal instruction methodologies and the content-achievement of ninth grade physical science students?

2. What are the relationships between concrete instruction and formal instruction methodologies and the intellectual development of ninth grade physical science students?

3. What are the relationships between concrete instruction and formal instruction methodologies and learner I.Q. changes of ninth grade physical science students?

4. What are the relationships between concrete instruction and formal instruction methodologies and the retention of gains made in content-achievement of ninth grade physical science students?

5. What are the relationships between concrete instruction and formal instruction methodologies and the retention of gains made in intellectual development of ninth grade physical science students?

Hypotheses

The following hypotheses were tested by statistical analysis of the data:

H_0 Ninth grade students will not show significantly greater content-achievement in physical science when experiencing concrete instruction than those students experiencing formal instruction.

H_1 Ninth grade physical science students who experience concrete instruction will show significantly greater content-achievement than students who experience formal instruction.

H_0 Ninth grade physical science students experiencing concrete instruction will not show significantly greater intellectual development gains than those experiencing formal instruction.

H_2 Ninth grade physical science students who experience concrete instruction will show significantly greater intellectual development gains than students who experience formal instruction.

H_0 Ninth grade physical science students experiencing concrete instruction will not show significantly greater I.Q. gains than those experiencing formal instruction.

H_3 Ninth grade physical science students who experience concrete instruction will show significantly greater I.Q. gains than students who experience formal instruction.

H_0 The content-achievement gains made by the group experiencing concrete instruction will not be significantly more lasting than those made by the group experiencing formal instruction.

H_4 The content-achievement gains made by the group experiencing concrete instruction will be significantly more lasting than those made by the group experiencing formal instruction.

H_0 The intellectual development gains made by the group experiencing concrete instruction will not be significantly more lasting than those made by the group experiencing formal instruction.

H_5 The intellectual development gains made by the group experiencing concrete instruction will be significantly more lasting than those made by the group experiencing formal instruction.

CHAPTER II

REVIEW OF THE LITERATURE

This study was designed to investigate the relationships among concrete instruction, formal instruction, content-achievement, intellectual development and learner I.Q. for ninth grade physical science students. Although no study has been conducted which addresses itself to these precise variables several related studies have been conducted which led to an acute need for this investigation.

Lawson[2] investigated the understanding of concrete and formal operational concepts by concrete and formal operational students in secondary school science classes. His study determined that formal operational students are able to develop an understanding of both formal operational and concrete operational concepts while concrete operational students are able to develop an understanding of concrete operational concepts only. He concluded that concrete operational concepts only should be attempted to be taught to concrete operational students with the recommendation

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[2]Anton Eric Lawson, "Relationships Between Concrete and Formal Operational Science Subject Matter and the Intellectual Level of the Learner" (unpublished Doctoral dissertation, University of Oklahoma, 1973).

that research is needed to determine the effect of teaching methodology on the amount of understanding concrete operational students acquire when experiencing differing teaching procedures and sequencing of materials.

Renner and Paske[3] have conducted an investigation to determine the effect of teaching methodology on the amount of learning that takes place in an introductory physics course designed for non-science majors at the University of Oklahoma. This investigation utilized formal instructional and concrete instructional techniques. Their study revealed that a significant difference exists between the amount of content learned in a formal instructional experience and a concrete instructional experience in favor of the concrete teaching method. Several Piagetian styled tasks were administered to determine the effect of teaching method on intellectual development with the results either showing no difference or slightly favoring the concrete group. In addition, an attitude questionnaire was administered to determine the students' feeling about the teaching method employed. The majority of students in the concrete instructional group indicated they liked the course while none in the formal instructional group liked the method, in fact seventy percent indicated they did not like the formal teaching method. Results of Piaget pre- and posttests indicated that students who initially are formal operational will show an increase in intellectual development when experiencing formal teaching. However, students who are initially concrete operational show markedly

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[3]John W. Renner and William C. Paske, "Comparing Two Forms of Instruction in College Physics" <u>American Journal of Physics</u>, Vol. 45, No. 9, September 1977, pp. 851-859

less intellectual development with formal teaching than with concrete teaching.

Sheehan[4] conducted an investigation designed to determine the effect of formal and concrete instruction on formal and concrete operational students. His study was designed to teach three concepts: Equilibrium in the balance bar, angles of incidence and reflection and oscillation of the pendulum to two groups of students of approximately the same size who had been identified as concrete operational and formal operational. Each concept was presented to the student, one each day for three consecutive days. According to Sheehan the study concluded that formal students showed greater achievement than concrete students regardless of the instructional mode and that concrete instruction was more effective with either concrete or formal operational students. The achievement was more durable for the formal operational students than for the concrete operational students with either concrete or formal instruction.

The results of Sheehan's study can be misleading, however. Two of the concepts he attempted to teach are formal concepts: i.e., equilibrium in the balance bar if extended to any ratio of distance times weight more complex than 1:2[5] and oscillation of the pendulum which utilized the

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[4]Donald J. Sheehan, "The Effectiveness of Concrete and Formal Instructional Procedures with Concrete- and Formal-Operational Students" (unpublished Doctoral Dissertation, State University of New York at Albany, 1970).

[5]Inhelder and Piaget, pp. 164-181.

ratio length is proportional to period.[6] The results of Lawson's study indicate concrete operational students are severely limited in their ability to comprehend these formal concepts. This may be offered as an argument to explain why the concrete operational students did not score higher with concrete instruction.

In addition the age group utilized in the study was 12 years 6 months to 13 years 5 months (approximately the eighth grade). Of the 189 students, 91 (48%) were identified as concrete operational, 81 (43%) as formal operational and 17 non-classifiable. Excluding the non-classifiable students the concrete operational students consisted of 53% and the formal operational students 47% of the sample. According to a study of the intellectual development level of students in Oklahoma[7] no more than 23% of students in the eighth grade have begun formal operational thinking with less than 2% completely formal operational. These data indicate that either the population utilized by Sheehan is markedly different than the population of Oklahoma students or that the criterea used to determine the operational level of the subjects is in error. The hypothesis may be advanced that the population of New York is not unlike the population of Oklahoma in terms of the intellectual development of this age group. If so, this would indicate that the sample utilized

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[6] Ibid., pp. 67-79

[7] John W. Renner, Don G. Stafford and William B. Ragan, Teaching Science in the Elementary School, (New York: Harper and Row, 1973), pp. 341-349.

in this study consisted of primarily concrete operational students, with the remainder only beginning formal operational thinking. In addition the possibility exists that the results of this study were severely limited due to the small amount of time (3 days) devoted to actual instruction of the concepts to be learned.

Grabber[8] conducted a study of parallel design that utilized 540 sophomore students in two classrooms from each of four different high schools to compare deductive-expository and inductive-discovery teaching methodologies in the acquisition and retention of science concepts, principles and processes. The experimental instruction was conducted during an eight week period. The results of this experiment showed no significant differences in initial learning of scientific ideas and process skills. The deductive-expository technique was found to be significantly greater in terms of retention.

[8] Arthur Henry Grabber "An Investigation of the Comparative Effectiveness of Deductive-Expository and Indctive-Discovery Teaching Strategies in the Acquisition and Retention of Science Concepts, Principles and Processes" (unpublished Doctoral dissertation, University of Connecticut, 1974).

CHAPTER III

EXPERIMENTAL DESIGN, DEFINITIONS AND EVALUATION OF THE SAMPLE

EXPERIMENTAL DESIGN

Selection of Subjects

Subjects for this study were selected from the population of approximately one hundred fifty ninth grade students from Noble Junior High School, Noble, Oklahoma. Forty-eight students were randomly assigned to one of two physical science classes according to class scheduling possibilities so as to make the two classes as homogeneous as possible. Each of the students had been identified by the counselor of the school to be an average student based on his grade the previous year in mathematics. (See item two under 'Limitations of the Study'.) Twenty-three students were assigned to the concrete instruction class and twenty-five to the formal instruction class.

Procedures

Two ninth grade physical science classes were utilized for this study for a period of sixteen weeks. One class was conducted using the concrete instruction methodology and the other class was conducted using the formal instruction methodology. The investigator instructed both classes to minimize the instructor variable. The topics covered were: (1) Static

Electricity; (2) Current Electricity; (3) Light and Optics; (4) Sound; (5) Magnetism; and (6) Electromagnetism. The students in each class were expected to learn the same content. The students were evaluated on the content-achievement by their performance on written examinations given at the conclusion of each of the topic areas. The evaluation of the permanence of gains made in content-achievement was determined by the students' performance on the same written examinations given approximately three months following the conclusion of the topic unit. The students were evaluated as to their intellectual development and I.Q. level by a statistical analysis of their performance on pretests given at the beginning of the first semester and posttests given at the end of the first semester. The evaluation of the permanence of gains made in intellectual development was determined by statistical analysis of a post-posttest given approximately three months following the conclusion of the experimental instruction.

Chronology of the Study

This experiment was conducted over a period of seven months from August 30, 1976 to March 30, 1977. The experimental instruction was done during the sixteen weeks between August 30, 1976 and December 17, 1976. Both the concrete instruction group and the formal instruction group studied the same content unit during the same time interval. Within those time intervals the two groups studied the science concepts at parallel rates and order of presentation. Classes met Monday through Friday with the exception of November 26 and 27, 1977

(Thanksgiving break). The concrete instruction group met during the second class period of the day (9:50 a.m. to 10:45 a.m.) for fifty five minutes and the formal instruction group met during the sixth and last class period of the day (2:20 p.m. to 3:20 p.m.) for sixty minutes. The students followed the same class schedule every day.

The administration of the Piagetian tasks for measurement of intellectual development was done by individually interviewing each student. A student to be interviewed was called from his class and typically took fifteen minutes to complete the tasks. The Piagetian pretest was administered during the days of September 6-10, 1976, the posttest during the days of December 15-17, 1976 and January 3-5, 1977 and the post-posttest during the days of March 28-30, 1977.

The I.Q. tests were administered by the instructor to each class during the regularly scheduled class period. The instructor followed the directions and time schedules as presented in the Examiners Manual for the Short Form Test of Academic Aptitude,[9] Level 5. The I.Q. pretest was administered on September 1, 1976 and the posttest was administered on December 16, 1976.

The content examinations were administered during the regularly scheduled class period for each group at the conclusion of each content unit. Both groups received the content examinations on the

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[9]Elizabeth T. Sullivan, Willis W. Clark and Ernest W. Teigs, Short Form Test of Academic Aptitude, Level 5 (Monterey, California: CTB/ McGraw-Hill, 1970).

same day. A student who was absent on the day of an examination was allowed to make up the examination for the purpose of giving him a grade in the course, but his score on the make up examination did not become a part of this study. The students received the multiple choice examination first. They then turned in their completed multiple choice examination to the instructor and recieved the free response examination. The students were not allowed to see both examinations at the same time, nor to refer back to the multiple choice examination while writing the free response examination.

The content post-examinations were given to students approximately three months following the conclusion of each topic unit in a manner similar to the administration of the content examinations. The content post-examinations were given unannounced.

After receiving the first two topic unit content post-examinations (Static Electricity and Current Electricity) several students in the formal instruction group verbally experssed their dislike of being asked to write the post-examinations. When asked to write the third post-examination (Light & Optics) approximately one-third of the students in the formal instruction group wrote unsolicited comments on their papers expressing their extreme dislike of being asked to write the post-examinations. One girl stated on her paper that she refused to write any further post-examinations. At this point the investigator met with this group of hostile students from the formal instruction group and asked them to write only one more post-examination (Sound) on the condition that the last two unit content post-examinations

(Magnetism and Electromagnetism) would be omitted. The students agreed and after writing the post-examination for Sound the study was terminated.

Instruments

The written examinations to be used for evaluation of content-achievement were developed by the investigator. Two types of instruments were utilized for measurement of content-achievement for each topic area. One consisted of multiple choice items in combination with a written response by the student as to the reasoning behind his choice. The second type of content evaluation instrument consisted entirely of free response items. The instruments were designed to test for applications of the scientific concepts the students were expected to learn. These content examinations are presented in Appendix A.

The content examinations were judged to be valid by the investigator and that face validity was supported by Dr. John W. Renner. The reliability estimates of each content examination were calculated using the Spearman-Brown split half method. Raw data relating to the reliability estimates are presented in Tables E-1 and E-2. The reliability was obtained by dividing each content examination into odd and even items. The scores on the two halves were then correlated to provide a reliability coefficient for a half test. The reliability coefficient estamate for the entire examination was then calculated using the Spearman-Brown formula: $r_{xx} = \frac{2r_{hh}}{1+r_{hh}}$

where r_{hh} is the reliability of the half test and r_{xx} is the reliability estimate of the whole test.

The reliability estimates of each content examination are presented in Table E-3. They are: Static Electricity; multiple choice 0.073, free response 0.584, Current Electricity; multiple choice 0.593, free response 0.678, Light and Optics; multiple choice 0.603, free response 0.246, Sound; multiple choice 0.236, free response 0.811, Magnetism; multiple choice 0.471, free response 0.632, Electromagnetism; multiple choice 0.302, free response 0.340. The content examination scores obtained for the end-of-unit tests were used based on the assumptions that because the content material was recently studied and due to the psycological pressure of being graded, the students would exhibit their best performance. Since a low reliability reduces the likelyhood of finding group differences, any observed differences would be intensified with more reliable measures.

The evaluation of intellectual development level for pretest, posttest and post-posttest was made by a statistical analysis of the performance by the student using four Piagetian tasks. The tasks used for this study were: (1) conservation of volume; (2) separation of variables; (3) equilibrium in the balance; and (4) colorless liquids.[10] The administration of the tasks was conducted by students from the

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[10]Barbel Inhelder and Jean Piaget, The Growth of Logical Thinking, (New York: Basic Books, Inc., 1958), pp. 164-181, 44-66, 107-122.

University of Oklahoma Science Education Center who had considerable experience with the tasks.[11]

The determination of I.Q. for pretest, and posttest was made using the Short Form Test of Academic Aptitude,[12] Level 5.

Statistical considerations

Hypothesis one was tested for a difference between the means of the level of content-achievement exhibited by the group experiencing concrete instruction and the group experiencing formal instruction according to the students' performance on content examinations administered at the conclusion of each teaching unit. Similarly hypothesis four was tested for a difference between the means for the permanence of content-achievement by a readministration of the content examinations at a three month interval following their presentation in the classroom. The Student's t-Ratio test was employed to determine significance between two means for data relating to these two hypotheses. Upon finding a significant difference in the means of the two groups an analysis of covariance was performed between the performance on content examinations and intellectual development level and between the performance on content examinations and I.Q. level to determine whether intellectual development and/or I.Q. level was responsible for the observed difference in content-achievement. This technique removes

[11]For a detailed discussion of protocol for the Piagetian tasks see John W. Renner, Evaluating Intellectual Development using Written Responses to Selected Science Problems, University of Oklahoma, 1976, Appendix A, pp. 139-151.

[12]Elizabeth T. Sullivan, Ibid.

the influence of the concomitant variable and analyzes the differences in content-achievement between the two groups after taking into account the initial differences of the covariate; i.e., intellectual development and/or I.Q. Thus the correlation between the measures of content-achievement and intellectual development and/or I.Q. is statistically controlled.

Hypothesis two was tested for a difference between the means of the intellectual development gains made by the students of the group experiencing concrete instruction and the group experiencing formal instruction. The experimental design utilized to test this hypothesis was one of pretest and posttest. Hypothesis five may be thought of as a continuation of hypothesis two and was tested for a difference in the permanence of intellectual development gains made by the group experiencing concrete instruction and the group experiencing formal instruction. The Student's t-Ratio test was employed to determine any significant differences.

Hypothesis three was tested for a difference between the means of I.Q. gains made by the group experiencing concrete instruction and the group experiencing formal instruction. The experimental design utilized to test this hypothesis was one of pretest and posttest. The Student's t-Ratio test was employed to determine any significant differences.

In establishing the level of significance to be used for statistical analysis a consideration of the possible types of error must be made. A Type I error results when the null hypothesis is rejected when it is actually true. A Type II error results when the null hypothesis is accepted when it is actually false. The five hypotheses were tested for the relationship between concrete and formal instruction methodologies and content-achievement, intellectual development, learner I.Q., permanence of content-achievement and permanence of intellectual development. In each case the learner was expected to exhibit greater gains from concrete instruction than from formal instruction and the null hypothesis should be rejected.

A Type I error means that no significant relationship existed between the tested variable and instruction method, yet it was concluded that there was a significant relationship. Committing Type I error would imply that concrete operational thinkers are able to make significantly greater gains from concrete instruction than from formal instruction for the variables tested when this actually is not the case. In terms of educational implementation, committing Type I error would indicate that a change in educational methodology from formal instruction to concrete instruction for ninth grade physical science students should be made. As in reality no significant difference exists between formal and concrete instruction, such a change would not effect the quality of education the students receive, the only detrimental effect would be the financial expenditure necessary to initiate the change in instruction method.

A Type II error means that a significant relationship exists between the tested variable and instruction method, yet it was concluded that there is not a significant relationship. Committing this type error would be detrimental because it would imply that concrete operational thinkers are able to exhibit gains as well from formal instruction as from concrete instruction for the variables tested. In terms of educational implementation, committing Type II error would indicate that since no significant difference exists between instruction method and the variable tested, no change in instruction methodology need be implemented, when in reality a significant difference does exist. The loss to the quality of education is that the less effective instruction method: i.e., formal instruction, would be continued at the expense of the student. Clearly, Type II error is the more serious in this research.

Due to the serious nature of committing Type II error a high level of significance should be employed in evaluating the statistical comparisons of the relationships between concrete and formal instruction and the tested variable. The precise level of significance to determine whether to accept or reject each null hypothesis has not been stated. Rather selected levels which were more significant than 0.20 have been reported so as to present a more detailed description of the analysis of data. The interpretation of the importance of the findings is left to the reader.

Limitations

The following factors govern the degree to which the results of this study may be generalized to other populations of science students.

1. The evaluation of concrete and formal instruction was based on gains made in content-achievement, intellectual development and learner

I.Q. The measuring instruments used for content-achievement were developed by the investigator and the results of the research must be viewed in terms of their reliability and validity. The measuring of intellectual development was made using Piagetian tasks whose validity has been established by Jean Piaget.[13] Evaluation of the students' performance on these tasks was done by students who were working on the Cognitive Analysis Project conducted at the University of Oklahoma Science Education Center under the direction of Dr. John W. Renner. These students had conducted approximately two hundered interviews each and had shown themselves to be reliable in their consistency of testing using the Piagetian tasks.[14] The measurement of I.Q. was made using the _Short Form Test of Academic Aptitude_,[15] Level 5 and any conclusion drawn of a relationship of concrete instruction and formal instruction to I.Q. level must be viewed in terms of the reliability and validity of that instrument.

2. This study contains the limitation of subject selection. Students identified as being above average by their grades in mathematics the previous year were removed from the general population of ninth grade students. Similarly, students identified as being below average by their grades in mathematics the previous year were removed from the general population of ninth grade students. A group to experience concrete instruction and a group to experience formal instruction were selected by

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[13]Inhelder and Piaget, _Ibid_.

[14]Renner, _Ibid_.

[15]Sullivan, _Ibid_.

randomly assigning the remaining average students according to class scheduling possibilities.

3. The sample of forty eight ninth grade students was taken from a total population of approximately one hundred thirty ninth grade students in a Junior High School with an enrollment of four hundred fifty students in the seventh, eighth and ninth grades. These students were from a rural community, about half lived outside the city limits. the students ranged in socio-economic level from lower to middle class.

DEFINITIONS

Concrete instruction and formal instruction represent two opposing teaching methodologies. The following definitions provide the conceptual framework by which each method of presentation of the content material was designed for each instruction method.

Concrete instruction

The instructional procedure utilized with the concrete instruction group consisted of implementing the learning cycle. The learning cycle consists of three phases: Exploration, conceptual-invention and discovery. Each concept was introduced to the students through the exploration. The exploration phase consisted of activities the students were to do and included the experiences of observing, measuring, experimenting, interpreting, predicting and model building. These experiences were guided by written material to give direction to the students' exploration but no specific information about the concept was given the students. The purpose of the exploration was to allow the students to develop understanding of the concept to be learned through actual first hand experience. Upon the completion of the exploration phase the conceptual-invention was made for the students. The conceptual-invention phase consisted of two parts: Naming the concept and checking students' understanding of the concept. The concept name gave the students a label to associate with their finding and checking student understanding of the concept consisted of their answering questions related to the data which had been collected. The purpose of the conceptual-invention phase was to give the students a name or label to describe the concept they had found through exploration and to allow the students to utilize the information they had obtained through exploration. Following the conceptual invention the students participated in the discovery phase of the learning cycle. The discovery consisted of the same types of activities as the exploration; that is, observing, measuring, experimenting, interpreting, predicting and model building. These activites were designed to further enhance the students' mental structures concerning the concept.

A typical day's class activity varied according to which phase of the learning cycle the students were experiencing. At the onset of an investigation the students received the first page of the exploration directions which described the procedure they were to follow. The students then completed activities outlined on the first page and upon approval of the instructor began working on the next page. An average of three pages was found to be a full period of work for the students; the faster students were allowed and encouraged to help and work with the slower students toward the close of each class session. When the group had completed the exploration phase the class was seated and the conceptual-invention was presented. The invention was given to the students in written form with the instructor reviewing the exploration and orally describing the concept. The students then completed the "Understanding the Concept" questions which would typically require fifteen minutes. The students were then given the first page of the discovery activities and proceeded in a manner similar to the activities of the exploration phase. Upon completion of the discovery a short review session was conducted with the instructor making reference to major ideas and asking question pertinent to the concept. A complete learning cycle typically required five to seven days.

Formal Instruction

The instructional procedure utilized for the formal instruction group consisted of the instructor directly giving the students all the information pertaining to the concept that they were expected to know. The procedures used to transmit information consisted of: (1) the students taking lecture notes from an overhead projector, (2) the students taking notes from filmstrips, (3) the students taking notes from motion pictures and (4) reading assignments from a textbook related to the concept. The students were not asked to find something for themselves, rather the information was presented to them by one of the four procedures just described. The instructor presented the lectures by mainly using declarative sentences. In addition the students were given a worksheet of questions and/or problems directly related to the day's lesson and allowed to complete the sheet while the instructor was available to answer questions and assist the students with areas unclear to them. The worksheet questions could be answered by consulting the day's notes and the problems were parallel to examples given in the day's notes.

A typical day's activity was for the instructor to use the first twenty to thirty minutes of class giving the students the content for that day with one or more of the four methods described. During a lecture the students were required to take notes on the lecture material that was presented on an overhead projector. At other times the students were shown a film or filmstrip. During a motion picture the projector was stopped periodically and the instructor told the students what to write in their notes about the concept. During a filmstrip the students were expected to write in their notes the caption of the visual when the instructor considered it appropriate. In the case of reading assignments the class was given the first portion of class time to do the reading. This was done to assure as much as possible that the reading was actually done rather than giving reading as a homework assignment with the possibility of it not being completed. These four instructional procedures overlapped in terms of content material. The purpose of the repetition was to provide the students with as much opportunity as possible to acquire the content material, within the framework of formal instruction. The remaining portion of class time was utilized by the students completing a worksheet of problems and/or questions under direct supervision of the instructor. The worksheet was designed so that approximately three-fourths of it could be completed in class by most students. The students were allowed to take the worksheet home if in the opinion of the instructor effort had been made to complete it in class.

EVALUATION OF THE SAMPLE

The sample utilized for this investigation was initially thought to be an average sample with both high achievers and low achievers removed. (See item 2 under "Limitations of the Study.") This grouping of students had been done by the school system prior to the design of the study. An analysis of this sample compared to the Oklahoma population was performed.

Two measures were initially given the students as a pretest. The students were measured as to their intellectual development using four Piagetian styled tasks as listed in Chapter One. Raw data from these tasks are presented in Table 5-1. The students' intellectual development was then compared to the Oklahoma population according to a study of the intellectual level of Oklahoma students by John W. Renner and Donald G. Stafford.[16] Those data were obtained using six Piagetian tasks: (1) conservation of solid amount, (2) conservation of weight, (3) conservation of volume, (4) elimination of contradictions,

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[16]John W. Renner, Don G. Stafford and William B. Ragan, <u>Teaching Science in the Elementary School</u>, (New York: Harper and Row, 1973), pp. 341-349.

(5) conservation of volume using two identically shaped cylinders of different weights and (6) exclusion of irrelevant variables. The tasks were administered to 588 subjects ranging from the seventh to twelfth grades. The data collected for the ninth grade in that study was used as the standard for the Oklahoma population. For the standard a combined score for the six tasks of six to eleven was classified as concrete operational, twelve and thirteen as post concrete operational and fourteen through sixteen as formal operational. The corresponding classifications using the four Piagetian tasks of the present investigation are four to eight concrete operational, nine through eleven post concrete operational and twelve through fifteen formal operational. Table 3-1 contains a summary of the Piagetian pretest of the present investigation and the Oklahoma standard.

TABLE 3-1

PIAGETIAN PRETEST AND PIAGETIAN STANDARD
FOR OKLAHOMA POPULATION

Piaget Level	Score	Concrete Instruction	Formal Instruction	Combined Sample	Score	Oklahoma Population
Concrete	4-8	19 (83%)	19 (76%)	38 (79%)	6-11	78 (83%)
Post Concrete	9-11	3 (13%)	6 (24%)	9 (19%)	12-13	7 (7%)
Formal	12-15	1 (4%)	0 (0%)	1 (2%)	14-16	9 (10%)
Post Concrete and Formal	9-15	4 (17%)	6 (24%)	10 (21%)	12-16	16 (17%)
		N = 23	N = 25	N = 48		N = 94

The precentage of concrete operational students (79%) was close to the Oklahoma population (83%) for the combined sample. The percentage of post concrete and formal operational students (21%) was also close to the Oklahoma population (17%). However deviations were much larger for the percentage of post concrete operational students (19%) and the Oklahoma population (7%) and formal operational students (2%) and the Oklahoma population (10%). The data indicated that there were fewer formal operational students in the present study than would be expected in a random sampling of Oklahoma ninth grade students.

A t-Ratio test was performed to determine any significant difference in the means of the intellectual development level of the two instruction groups. The results of this test are presented in Table 3-2.

TABLE 3-2

MEANS, STANDARD DEVIATIONS, t-RATIO AND SIGNIFICANCE LEVELS FOR PIAGETIAN PRETEST

Piagetian	Concrete Instruction		Formal Instruction				
Task	Mean	S. Dev.	Mean	S. Dev	t	df.	p
Con. Vol.	2.09	0.95	2.16	0.80	0.289	46	>0.20
Sep. Var.	1.78	0.60	1.88	0.60	0.562	46	>0.20
Equ. Bal.	1.26	0.45	1.40	0.71	0.806	46	>0.20
Col. Liq.	1.87	0.69	1.80	0.50	0.401	46	>0.20
Total	7.00	2.11	7.24	1.83	0.422	46	>0.20

The calculated t-Ratio for each Piagetian task as well as the total fell below the 0.851 required at the 0.20 level of significance. Therefore the null hypothesis that no significant difference existed between the means of the intellectual development level of the concrete instruction group and the formal instruction group at the onset of the study was accepted.

The students' I.Q. was measured using the <u>Short Form Test of Academic Aptitude</u>,[17] Level 5. Raw data from this instrument are presented in Table 7-1. The standardized mean of this measure is 100 and the standard deviation is 16. The summary of the pretest data is presented in Table 3-3.

TABLE 3-3

MEANS, STANDARD DEVIATIONS FOR I.Q. PRETEST AND STANDARDIZED MEAN AND STANDARD DEVIATION

	Language		Non-Language		Overall	
	Mean	S. Dev.	Mean	S. Dev.	Mean	S. Dev.
Concrete Instruction	95.39	10.74	100.65	12.39	98.43	9.99
Formal Instruction	97.36	9.82	98.80	10.91	98.20	9.91
Combined Sample	96.42	10.21	99.69	11.56	98.31	9.87
Standard	100.00	16.00	100.00	16.00	100.00	16.00

The means ranged from 95.18 to 100.23. The standard deviations ranged from 9.82 to 12.51. The means were close to the standardized mean, however the standard deviations fell short of the standardized standard deviation considerably. The data indicated that while the means of the sample group were close to the normal population the low

[17]Sullivan, <u>Ibid</u>.

standard deviations indicated an abnormally high clustering of the students' I.Q. around the mean.

A t-Ratio test was performed to determine any significant difference in the means of the I.Q. of the two instruction groups. The results of this test are presented in Table 3-4.

TABLE 3-4

MEANS, STANDRAD DEVIATIONS, t-RATIO AND SIGNIFICANCE LEVELS FOR I.Q. PRETEST

I.Q.	Concrete Instruction		Formal Instruction				
	Mean	S. Dev.	Mean	S. Dev.	t	df.	p
Language	95.39	10.74	97.36	9.82	0.664	46	>0.20
Non-Language	100.65	12.39	99.80	10.91	0.551	46	>0.20
Overall	98.43	9.99	98.20	9.96	0.081	46	>0.20

The calculated t-Ratio for all three portions of the instrument fell well below the 0.851 required at the 0.20 level of significance. Therefore the null hypothesis that no significant difference existed between the means of the I.Q. of the concrete instruction group and formal instruction group at the onset of the study was accepted.

CHAPTER IV

CONTENT ACHIEVEMENT

Content Examinations

The purpose of this investigation was to determine the relationship of concrete and formal instruction to content-achievement, I.Q. and intellectual development. The expectation was that students experiencing concrete instruction would exhibit significantly greater gains than students experiencing formal instruction for each of the three dependent variables.

Hypothesis one was tested for significant differences between the means of the content-achievement exhibited by the concrete instruction group and the formal instruction group. The multiple choice and free response content examinations were given each student at the conclusion of each content unit.

Both the multiple choice and the free response examinations were scored by the investigator. Precautions were taken to avoid bias when scoring the examinations. A random number generator was used to obtain four digit random numbers which were used as identification numbers. After checking to eliminate duplicate numbers, the numbers were written in the space for the students name on the examinations by the investigator using the same pen. Each student was then assigned one of these numbers and given the corresponding examination. Before scoring the examinations another person mixed the examinations from both groups of students out of the presence of the investigator. New random numbers were used for each set of examinations to prevent the investigator from becoming familiar with any student's identification number. The students were instructed not to put their names on the examination papers.

The investigator scored one item on all papers before going to the next item and every effort was made to score all papers at one setting for each item. The following scheme was used for scoring the multiple choice examinations. Ten points were awarded for a correct multiple choice selection and an explanation that supported that selection. Five points were awarded for an incorrect multiple choice selection, but an explanation that supported the correct selection. No points were awarded for a correct selection, but an explanation that did not support that selection or no explanation. No points were awarded for an incorrect selection, and an explanation that did not support the correct selection or no explanation. The free response examinations were scored according to the subjective evaluation of the investigator. Every effort was made to score these responses as consistantly as possible. While scoring the examinations the investigator was not aware of which group a given paper was from.

Following the scoring of all the items, the papers were matched with the student's name and the scores were recorded. The recorded scores were expressed in percentile correct points and are presented in Tables 4-1 and 4-2. The content examinations are presented in Appendix A.

The means, standard deviations, t-Ratios and significance levels for the multiple choice content examinations are presented in Table 4-3. Similar statistics for the free response examinations are presented in Table 4-4. Figure 4-1 shows a comparison of the means of the multiple choice examinations and Figure 4-2 shows a comparison of the means of the free response examinations.

With the exception of the Static Electricity examinations the group experiencing concrete instruction evidenced greater content-achievement than the group experiencing formal instruction. The level of significance ranges from this difference being not significant at the 0.20 level to being significant at the 0.0005 level.

In the case of Static Electricity the greater mean evidence by the formal instruction group was significant at the 0.10 level for the multiple choice examination and was not significant at the 0.20 level for the free response examination. Three possible reasons are offered to explain this apparent anomaly. (1) The unit on Static Electricity was encountered first. During this time the experimenter was becoming more familiar with the two opposing teaching methods. The possibility exists that the dichotomy between concrete instruction and formal instruction methodologies was not as marked as with successive units. (2) The concrete instruction technique utilized extensive student experimentation with objects. During the time this unit was scheduled the humidity

TABLE 4-1

RAW DATA FOR CONTENT EXAMS - MULTIPLE CHOICE

Student No.	Static Elect.	Current Elect.	Light & Optics	Sound	Magnet- ism	Electro- magnetism	Overall Average
1	23	50	35	32	66	11	36.17
2	40	50	50	40	66	44	48.33
3	56	40	40	47	75	58	52.67
4	20	55	20	61	50	27	38.33
5	25	55	20	43	75	33	41.83
6	28	27	30	29	50	27	31.83
7	31	45	40	36	33	22	34.50
8	28	50	20	43	66	11	36.33
9	48	60	60	86	41	51	57.67
10	*	55	40	47	66	38	49.20
11	35	45	30	54	75	34	45.50
12	43	60	15	43	66	22	41.50
13	10	50	50	69	33	33	40.83
14	51	50	70	57	100	51	63.17
15	33	57	60	26	50	33	43.16
16	28	50	20	33	41	11	30.50
17	40	60	40	57	58	38	48.83
18	56	45	15	47	50	5	36.33
19	*	70	50	57	58	35	54.00
20	35	50	5	29	16	22	26.17
21	48	60	40	44	66	36	49.00
22	0	55	35	64	41	50	40.83
23	15	7	30	29	0	50	21.83
24	*	*	35	43	66	55	49.75
25	43	40	0	43	50	44	36.67
26	33	*	0	86	16	*	33.75
27	*	17	40	29	33	0	23.80
28	60	20	0	47	50	22	33.17
29	59	10	35	47	58	33	40.33
30	30	30	25	26	83	11	34.17
31	23	0	0	43	50	16	22.00
32	46	55	40	47	50	55	48.83
33	43	30	25	40	50	11	33.17
34	8	0	0	29	0	0	6.17
35	55	10	10	71	16	0	27.00
36	28	0	5	7	50	0	15.00
37	40	10	55	54	50	55	44.00
38	26	15	20	19	41	16	22.83
39	40	0	30	33	16	0	19.83
40	38	30	10	43	33	55	34.83
41	38	10	10	40	41	27	27.67
42	48	17	20	57	58	33	38.83
43	23	22	33	61	0	22	26.83
44	31	22	30	50	75	5	35.50
45	60	28	35	71	100	27	53.50
46	60	15	35	76	50	22	43.00
47	28	10	25	57	16	0	22.67
48	*	*	0	0	0	22	5.50

*Indicates that the student was absent on the day of the examination.
Students No. 1-23 experienced Concrete Instruction.
Students No. 24-48 experienced Formal Instruction.

TABLE 4-2

RAW DATA FOR CONTENT EXAMS - FREE RESPONSE

Student No.	Static Elect.	Current Elect.	Light & Optics	Sound	Magnet-ism	Electro-magnetism	Overall Average
1	42	59	51	71	41	27	48.50
2	32	43	41	53	79	11	43.17
3	68	41	29	24	74	52	48.00
4	40	53	24	56	31	28	38.67
5	38	44	40	20	41	17	33.33
6	32	44	34	36	73	44	43.83
7	70	41	27	71	43	32	47.33
8	53	53	39	6	55	*	41.20
9	54	81	83	77	73	43	68.50
10	51	51	50	61	66	27	51.00
11	50	39	47	71	76	63	57.67
12	42	57	46	60	41	22	44.67
13	64	67	44	51	44	21	48.50
14	88	67	71	70	70	43	68.17
15	69	46	47	64	38	17	46.83
16	37	37	19	54	50	8	34.17
17	65	56	81	57	53	21	55.50
18	83	43	53	31	56	30	49.33
19	21	70	27	39	79	36	45.33
20	51	40	31	31	31	16	33.33
21	44	*	43	53	85	32	51.40
22	8	37	36	43	41	56	36.83
23	33	0	13	0	23	16	14.17
24	63	*	56	71	73	22	57.00
25	56	34	29	53	51	19	40.33
26	24	*	36	14	63	*	34.25
27	1	26	26	0	49	11	18.83
28	66	53	36	14	73	11	42.17
29	26	20	36	57	41	17	32.83
30	78	34	37	13	81	4	41.17
31	86	67	46	34	48	28	51.50
32	76	79	49	0	54	28	47.67
33	63	31	43	0	38	10	30.83
34	20	46	0	39	23	0	21.33
35	45	43	23	39	41	19	35.00
36	48	7	9	13	38	0	19.17
37	47	24	44	49	50	19	38.83
38	46	7	26	39	16	11	24.17
39	48	20	33	14	44	16	29.17
40	44	24	41	50	50	30	39.83
41	71	7	10	60	36	0	30.67
42	98	37	50	0	69	30	47.33
43	40	16	39	29	0	10	22.33
44	60	36	40	53	75	19	47.17
45	63	61	61	67	59	39	58.33
46	39	19	50	43	41	9	33.50
47	39	11	21	39	19	19	24.67
48	9	*	0	0	23	16	9.60

*Indicates that the student was absent on the day of the examination.
Students No. 1-23 experienced Concrete Instruction.
Students No. 24-48 experienced Formal Instruction.

TABLE 4-3

MEANS, STANDARD DEVIATIONS, t-RATIOS AND SIGNIFICANCE LEVELS FOR MULTIPLE CHOICE CONTENT EXAMINATIONS

Content	Concrete Instruction		Formal Instruction				
Examination	Mean	S. Dev.	Mean	S. Dev.	t	df.	p
Static Elect.	33.00	14.82	39.09	14.16	1.378	41	<0.10
Current Elect.	49.83	12.62	17.77	13.90	8.108	43	<0.0005
Light & Optics	35.43	16.44	20.72	16.18	3.124	46	<0.005
Sound	46.65	14.92	44.76	20.29	0.365	46	>0.20
Magnetism	54.00	21.48	42.08	27.73	1.734	46	<0.05
Electromag.	32.26	14.61	22.13	19.38	2.018	45	<0.05
Average	42.13	10.03	31.15	12.40	3.354	46	<0.005

TABLE 4-4

MEANS, STANDARD DEVIATIONS, t-RATIOS AND SIGNIFICANCE LEVELS FOR FREE RESPONSE CONTENT EXAMINATIONS

Content	Concrete Instruction		Formal Instruction				
Examination	Mean	S. Dev.	Mean	S. Dev.	t	df.	p
Static Elect.	49.35	19.28	50.24	23.34	0.144	46	>0.20
Current Elect.	48.59	16.16	31.91	19.85	3.056	46	<0.005
Light & Optics	42.43	17.74	33.64	16.28	1.791	46	<0.05
Sound	47.78	21.29	31.60	23.08	2.518	46	<0.01
Magnetism	54.91	18.33	46.20	20.16	1.562	46	<0.10
Electromag.	30.09	14.88	16.13	10.21	3.738	44	<0.0005
Average	45.62	11.59	35.11	12.46	3.022	46	<0.005

FIGURE 4-1

CONTENT EXAMINATION MEANS

MULTIPLE CHOICE

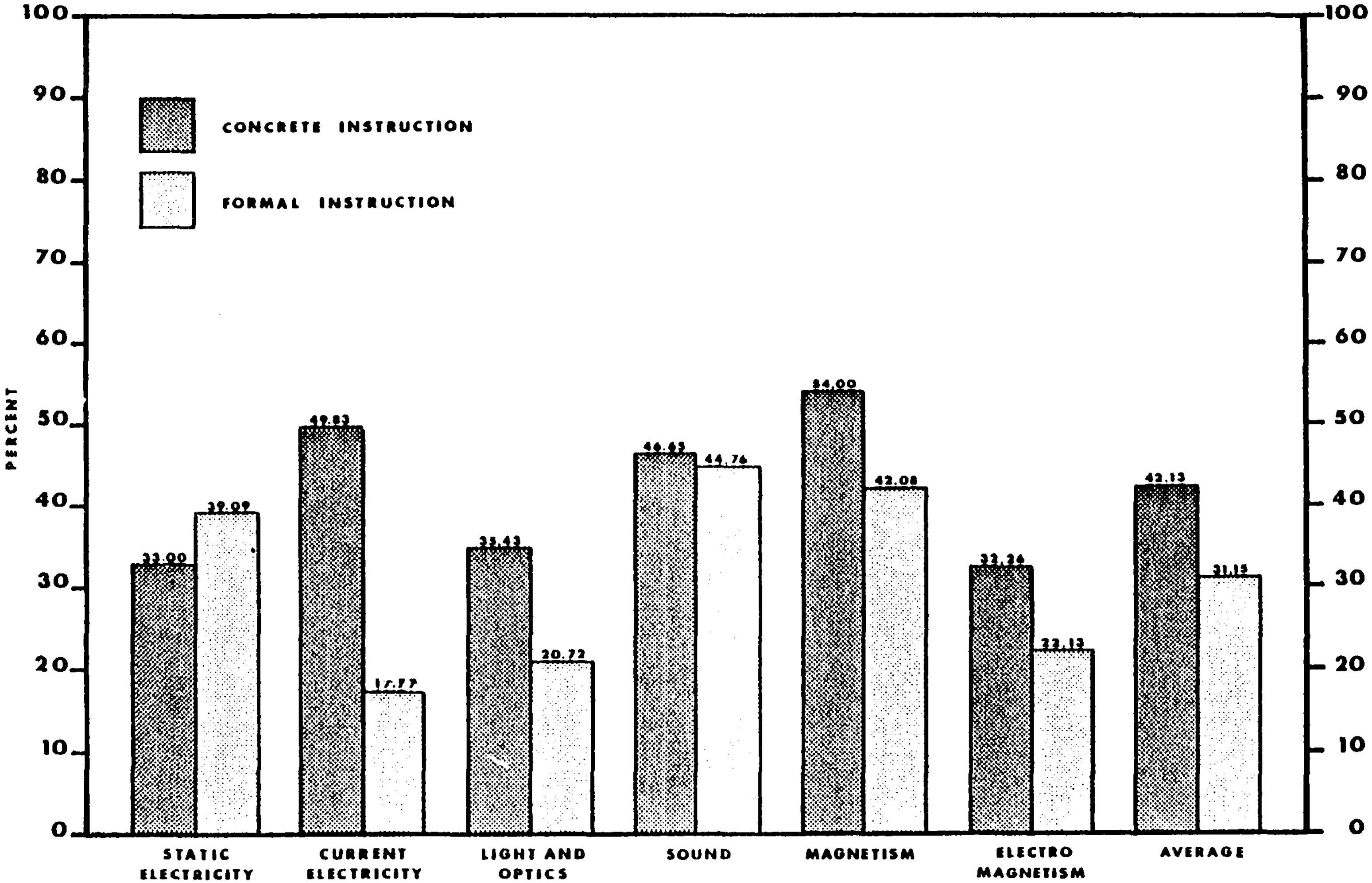
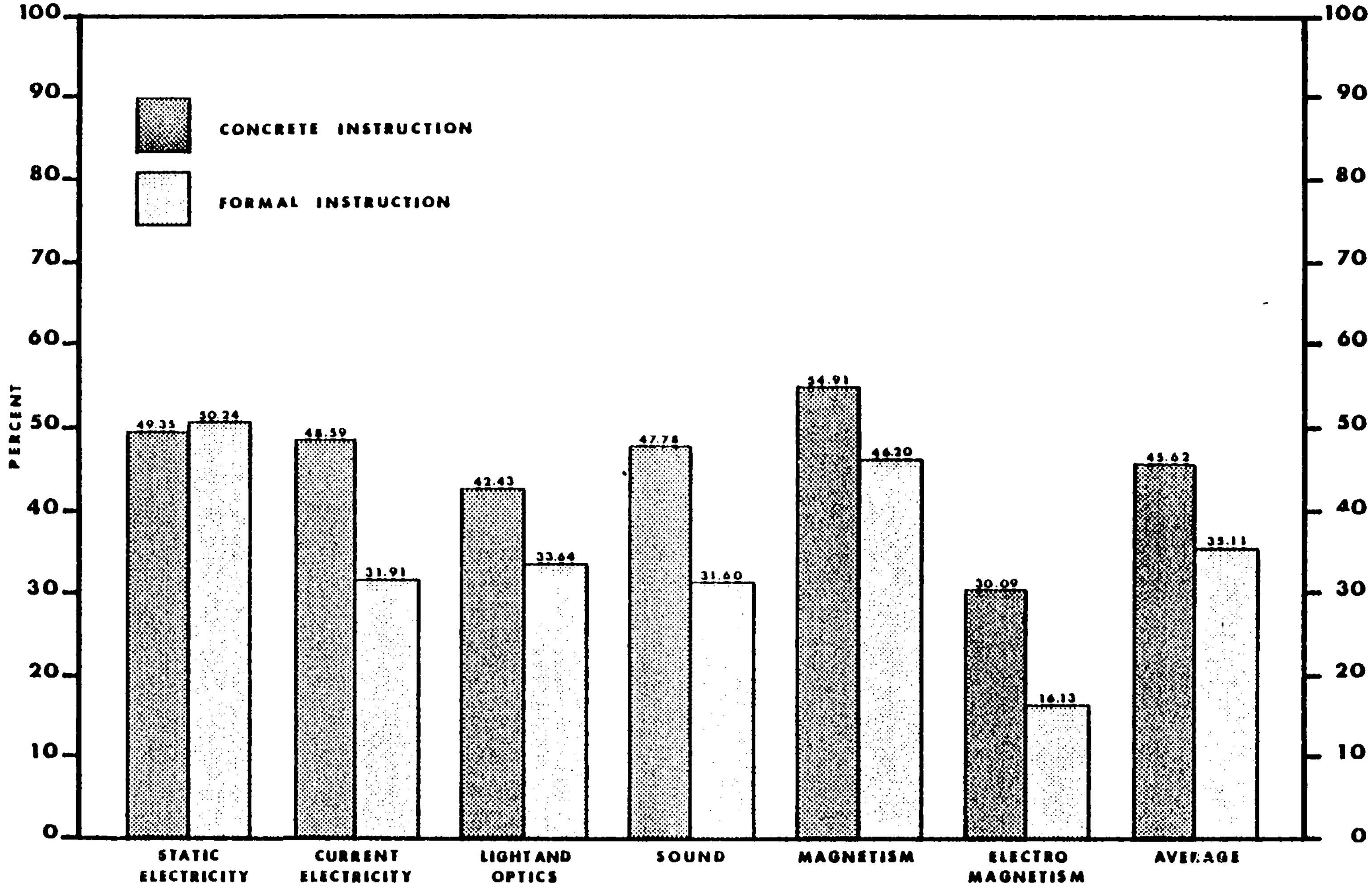


FIGURE 4 2

CONTENT EXAMINATION MEANS

FREE RESPONSE



very high making the interaction resulting from the static electricity equipment difficult to achieve. This could have led to erroneous conclusions based on inadequate correct data collected by the student. (An example: Vigorous rubbing with wool on a rubber rod was required to charge an electroscope. This caused the rod to heat, thereby opening the possibility of the student thinking heat charged the electroscope instead of static electricity.) In addition content material not obtained directly from actual first hand experience with objects, situations and/or events is not concrete instruction. In this case, the instructor was forced to either demonstrate how the apparatus was supposed to work or tell the student how it should work. (3) Much of the content material encountered in Static Electricity concepts requires formal operational thinking; that is, the content was not directly obtainable from experience with objects, situations and/or events. Assuming this to be the case the expectation of finding little significant difference in content-achievement regardless of instruction methodology was not unreasonable.

Data from the unit on Current Electricity showed a significant difference between the means in favor of the concrete instruction group at the 0.0005 level for the multiple choice examination and at the 0.005 level for the free response examination. An analysis of covariance was performed to determine whether intellectual development or I.Q. was responsible for the observed difference in means. Results of the analysis are presented in Tables 4-5 and 4-6.

The obtained F-ratios were all greater than the 7.27 required for significance at the 0.01 level for 1 and 41 degrees of freedom. The

TABLE 4-5

ANALYSIS OF COVARIANCE, PIAGETIAN PRETEST
AND CURRENT ELECTRICITY, CONTENT EXAMINATIONS

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	1162.26	
	Within	42	159.10	73.07
Free Response	Between	1	3253.24	
	Within	41	276.54	11.764

TABLE 4-6

ANALYSIS OF COVARIANCE, I.Q. PRETEST
AND CURRENT ELECTRICITY CONTENT EXAMINATIONS

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	11266.70	
	Within	42	154.09	73.116
Free Response	Between	1	3017.60	
	Within	41	267.97	11.261

conclusion was drawn that neither intellectual development nor I.Q. differences were responsible for the observed difference between the means of the concrete ins-ruction group and the formal instruction group. Null hypothesis one was rejected at the 0.0005 level of significance for the multiple choice examination and at the 0.005 level of significance for the free response examination in favor of the concrete instruction group.

Data from the unit on Light and Optics showed a significant difference between the means at the 0.005 level for the multiple choice examination and at the 0.05 level for the free response examination. An analysis of covariance was performed to determine whether intellectual development or I.Q. was responsible for the observed difference in means. Results of the analysis are presented in Tables 4-7 and 4-8.

TABLE 4-7

ANALYSIS OF COVARIANCE, PIAGETIAN PRETEST AND LIGHT & OPTICS CONTENT EXAMINATIONS

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	2599.72	
	Within	45	271.56	9.573
Free Response	Between	1	971.05	
	Within	45	291.05	3.329

TABLE 4-8

ANALYSIS OF COVARIANCE, I.Q. PRETEST AND LIGHT & OPTICS CONTENT EXAMINATIONS

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	2545.29	
	Within	45	237.01	10.739
Free Response	Between	1	882.43	
	Within	45	212.77	4.147

The obtained F-ratios for the multiple choice examination were both greater than the 7.24 required for significance at the 0.01 level for 1 and 45 degrees of freedom. The conclusion was drawn that neither intellectual development nor I.Q. differences were responsible for the observed difference between the means of the concrete instruction group and the formal instruction group for the multiple choice examination. The obtained F-ratios for the free response examination were both less than the 4.06 required for significance at the 0.05 level. The indication was that both intellectual development and I.Q. differences were responsible for the observed differences in means for the concrete instruction group and formal instruction group. Null hypothesis one was rejected at the 0.005 level of significance for the multiple choice examination and with the above reservation rejected at the 0.05 level of significance for the free response examination in favor of the concrete instruction group.

Data from the unit on Sound showed no significant difference between the means of the multiple choice examination at the 0.20 level. The data showed a significant difference in favor of the concrete instruction group at the 0.01 level for the free response examination. An analysis of covariance was performed to determine whether intellectual development or I.Q. was responsible for the observed difference in means. Results of the analysis are presented in Tables 4-9 and 4-10.

TABLE 4-9

ANALYSIS OF COVARIANCE, PIAGETIAN PRETEST AND SOUND CONTENT EXAMINATION

Content Examination	Source of Variation	df.	Variance Estimates	F
Free Response	Between	1	3186.23	
	Within	45	504.19	6.319

TABLE 4-10

ANALYSIS OF COVARIANCE, I.Q. PRETEST AND SOUND CONTENT EXAMINATION

Content Examination	Source of Variation	df.	Variance Estimates	F
Free Response	Between	1	3322.31	
	Within	45	497.92	6.672

The obtained F-ratios were both greater than the 4.06 required for significance at the 0.05 level for 1 and 45 degrees of freedom but less than the 7.24 required for the 0.01 level. The conclusion was drawn that neither intellectual development nor I.Q. differences were responsible for the observed difference between the means of the concrete instruction group and formal instruction group. Null hypothesis one was accepted for the multiple choice examination and rejected at the 0.01 level for the free response examination in favor of the concrete instruction group.

Data from the unit on Magnetism showed a significant difference between the means at the 0.05 level for the multiple choice examination and at the 0.0005 level for the free response examination in favor of the concrete instruction group. An analysis of covariance was performed to determine whether intellectual development or I.Q. was responsible for the observed difference in means. Results of the analysis are presented in Tables 4-11 and 4-12.

The obtained F-ratios were all less than the 4.06 required for significance at the 0.05 level for 1 and 44 degrees of freedom. The indication was that both intellectual development and I.Q. differences were responsible for the observed differences in means for the concrete

TABLE 4-11

ANALYSIS OF COVARIANCE, PIAGETIAN PRETEST AND MAGNETISM CONTENT EXAMINATIONS

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	1762.91	
	Within	45	574.91	3.066
Free Response	Between	1	1079.80	
	Within	45	336.99	3.204

TABLE 4-12

ANALYSIS OF COVARIANCE, I.Q. PRETEST AND MAGNETISM CONTENT EXAMINATIONS

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	1504.79	
	Within	45	434.56	3.463
Free Response	Between	1	859.39	
	Within	45	272.64	3.152

instruction group and formal instruction group. With the above reservation null hypothesis one was rejected at the 0.05 level of significance for the multiple choice examination and rejected at the 0.10 level of significance for the free response examination in favor of the concrete instruction group.

Data from the unit on Electromagnetism showed a significant difference between the means for the multiple choice examination at the 0.05 level and a significant difference between the means at the 0.0005 level for the free response examination. An analysis of covariance was performed to determine whether intellectual development or I.Q. was responsible for the observed difference in means. Results of the analysis are presented in Tables 4-13 and 4-14.

TABLE 4-13

ANALYSIS OF COVARIANCE, PIAGETIAN PRETEST AND ELECTROMAGNETISM CONTENT EXAMINATIONS

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	1278.09	
	Within	44	280.46	4.557
Free Response	Between	1	2296.16	
	Within	43	158.93	14.448

TABLE 4-14

ANALYSIS OF COVARIANCE, I.Q. PRETEST AND ELECTROMAGNETISM CONTENT EXAMINATIONS

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	1118.38	
	Within	44	239.22	4.675
Free Response	Between	1	2182.63	
	Within	43	148.41	14.706

The obtained F-ratios for the multiple choice examination were greater than the 4.06 required for significance at the 0.05 level. The obtained F-ratios for the free response examination were greater than the 7.27

required for significance at the 0.01 level. The conclusion was drawn that neither intellectual development nor I.Q. differences were responsible for the observed difference between the means of the concrete instruction group and formal instruction group for the free response examination. Null hypothesis one was rejected at the 0.05 level of significance for the multiple choice examination and rejected at the 0.0005 level of significance for the free response examination in favor of the concrete instruction group.

Overall averages were computed for each student for the content examinations. These averages showed a significant difference between the means at the 0.005 level for both the multiple choice and the free response content examinations. An analysis of covariance was performed to determine whether intellectual development or I.Q. were responsible for the observed difference in the means of the overall averages. Results of the analysis are presented in Tables 4-15 and 4-16.

TABLE 4-15

ANALYSIS OF COVARIANCE, PIAGETIAN PRETEST AND OVERALL AVERAGE CONTENT EXAMINATIONS

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	1528.39	
	Within	45	122.36	12.491
Free Response	Between	1	1439.84	
	Within	45	133.55	10.781

TABLE 4-16

ANALYSIS OF COVARIANCE, I.Q. PRETEST
AND OVERALL AVERAGE CONTENT EXAMINATIONS

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	1393.44	
	Within	45	77.33	18.019
Free Response	Between	1	1279.35	
	Within	45	85.20	15.015

The obtained F-ratios were all greater than the 7.27 required for significance at the 0.01 level for 1 and 45 degrees of freedom. The conclusion was drawn that neither intellectual development nor I.Q. differences were responsible for the observed difference between the means of the concrete instruction group and formal instruction group. Null hypothesis one was rejected at the 0.005 level of significance for both the multiple choice overall average and free response overall average in favor of the concrete instruction group.

Content Post-Examinations

Hypothesis four states that the retention of gains made in content-achievement was expected to be greater for the group experiencing concrete instruction than for the group experiencing formal instruction. Raw data for the content post-examinations are presented in Tables 4-17 and 4-18. The post-examinations were each given approximately three months after the corresponding content examinations. Data relating to this hypothesis were tested for a significant difference between the means using the

TABLE 4-17

RAW DATA FOR CONTENT POST-EXAMINATIONS - MULTIPLE CHOICE

Student Number	Static Elect.	Current Elect.	Light & Optics	Sound	Overall Average
1	25	40	20	36	30.25
2	28	60	20	29	34.25
3	45	5	10	0	15.00
4	18	0	10	14	10.50
5	20	20	33	47	30.00
6	20	10	10	29	17.25
7	38	50	40	33	40.25
8	20	30	10	47	26.75
9	63	50	20	71	51.00
10	35	43	25	57	40.00
11	25	50	35	71	45.25
12	23	0	0	0	5.75
13	53	40	30	54	44.25
14	65	80	70	33	62.00
15	18	20	20	43	25.25
16	35	40	5	0	20.00
17	85	30	30	33	44.50
18	33	30	15	0	19.50
19	60	60	30	43	48.25
20	38	27	20	14	24.75
21	43	50	55	61	52.25
22	28	30	10	14	20.50
23	15	20	25	71	32.75
24	48	5	0	43	24.00
25	0	20	0	0	5.00
26	0	0	0	0	0.00
27	0	0	10	0	2.50
28	0	17	0	0	4.25
29	58	40	35	33	41.50
30	0	15	10	0	6.25
31	0	50	20	14	21.00
32	0	30	20	29	19.75
33	15	40	25	4	21.00
34	0	0	0	0	0.00
35	0	20	0	29	12.25
36	33	0	0	0	8.25
37	60	20	10	14	26.00
38	0	7	0	43	12.50
39	0	10	0	4	3.50
40	0	40	0	*	13.33
41	0	20	0	0	5.00
42	0	0	0	7	1.75
43	10	20	0	47	19.25
44	0	0	10	0	2.50
45	0	40	0	0	10.00
46	0	10	15	29	13.50
47	3	10	10	11	8.50
48	0	0	0	0	0.00

*Indicates that the student was absent on the day of the examination.
Students No. 1-23 experienced Concrete Instruction.
Students No. 24-48 experienced Formal Instruction.

TABLE 4-18

RAW DATA FOR CONTENT POST-EXAMINATIONS - FREE RESPONSE

Student Number	Static Elect.	Current Elect.	Light & Optics	Sound	Overall Average
1	36	45	40	60	45.25
2	44	74	28	57	50.75
3	68	49	7	13	34.25
4	24	21	2	10	14.25
5	38	36	30	14	29.50
6	24	29	32	45	32.50
7	78	34	24	17	38.25
8	80	39	20	27	41.50
9	78	77	47	64	66.50
10	36	64	60	64	56.00
11	50	49	32	50	45.25
12	81	34	8	0	30.75
13	38	34	40	42	38.50
14	92	53	32	57	58.50
15	70	14	32	14	32.50
16	38	21	20	17	24.00
17	76	49	37	34	49.00
18	34	63	34	38	42.25
19	70	64	20	45	49.75
20	42	36	31	0	27.25
21	44	39	35	60	44.50
22	28	39	27	45	34.75
23	12	11	18	52	23.25
24	74	29	7	57	41.75
25	0	35	5	57	24.25
26	46	20	25	28	29.75
27	22	10	20	0	13.00
28	44	22	12	0	19.50
29	16	22	32	41	27.75
30	24	12	24	28	22.00
31	30	30	28	60	37.00
32	42	60	35	18	38.75
33	52	22	30	21	31.25
34	0	32	0	0	8.00
35	30	29	40	14	28.25
36	18	8	0	0	6.50
37	36	19	14	21	22.50
38	18	5	12	20	13.75
39	18	12	17	21	17.00
40	20	10	5	*	11.67
41	2	7	5	14	7.00
42	0	17	0	45	15.50
43	44	12	12	45	28.25
44	14	22	22	34	23.00
45	40	43	32	20	33.75
46	30	9	32	45	29.00
47	26	15	21	24	21.50
48	0	7	0	5	3.00

*Indicates that the student was absent on the day of the examination.
Students No. 1-23 experienced Concrete Instruction.
Students No. 24-48 experienced Formal Instruction.

Student's t-Ratio test. Table 4-19 presents the means, standard deviations, the t-statistic and significance levels for each content post-examination and the overall averages. Figure 4-3 shows a comparison of the means of the multiple choice post-examinations and Figure 4-4 shows a comparison of the means of the free response post-examinations.

TABLE 4-19

MEANS, STANDARD DEVIATIONS, t-RATIO AND SIGNIFICANCE LEVELS FOR CONTENT POST-EXAMINATIONS

	Concrete Instruction		Formal Instruction				
	Mean	S. Dev.	Mean	S. Dev.	t	df.	p
Multiple Choice							
Static Elect.	36.22	18.32	9.08	18.96	5.035	46	<0.0005
Current Elect.	34.13	20.35	16.56	15.59	3.374	46	<0.0005
Light & Optics	23.61	16.12	6.60	9.76	4.462	46	<0.0005
Sound	34.78	23.48	12.79	16.40	3.735	45	<0.0005
Average	32.18	14.74	11.26	10.18	5.762	46	<0.0005
Free Response							
Static Elect.	51.35	22.81	25.84	18.71	4.250	46	<0.0005
Current Elect.	42.35	17.86	20.36	12.95	4.911	46	<0.0005
Light & Optics	28.52	13.03	17.20	12.50	3.071	46	<0.005
Sound	35.87	12.22	25.75	18.77	1.733	45	<0.05
Average	39.52	12.44	22.15	10.60	5.221	46	<0.0005

FIGURE 4-3
CONTENT POST-EXAMINATION MEANS, MULTIPLE CHOICE

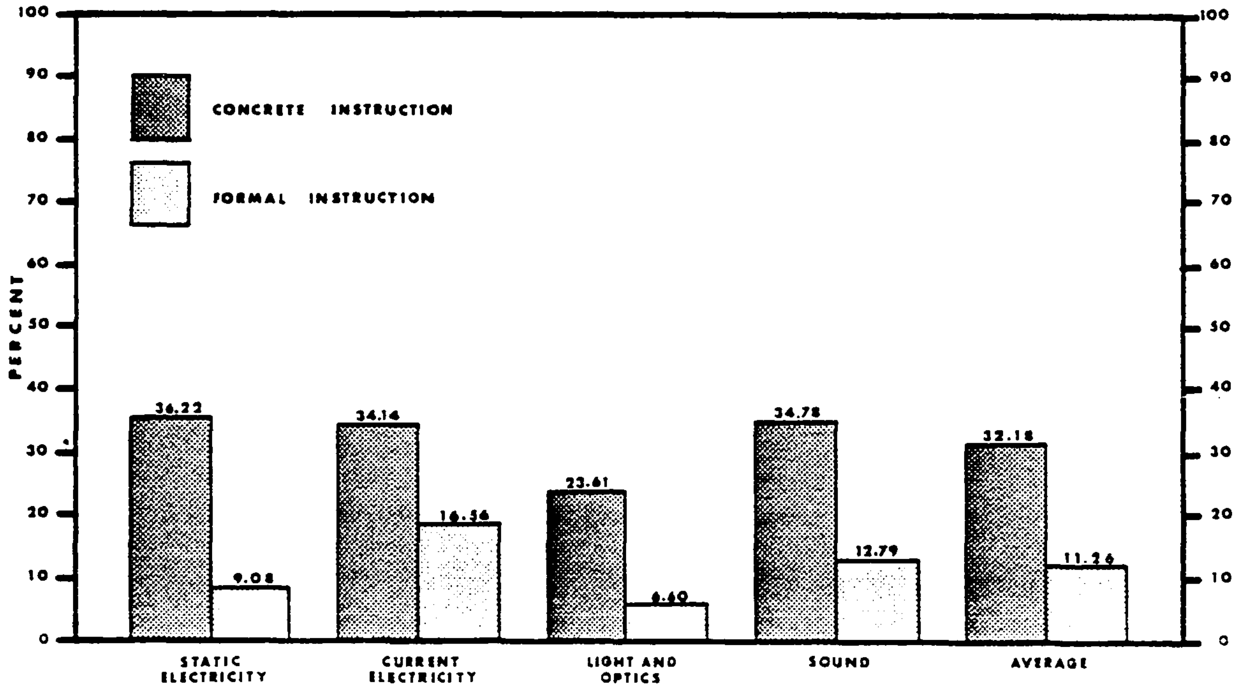
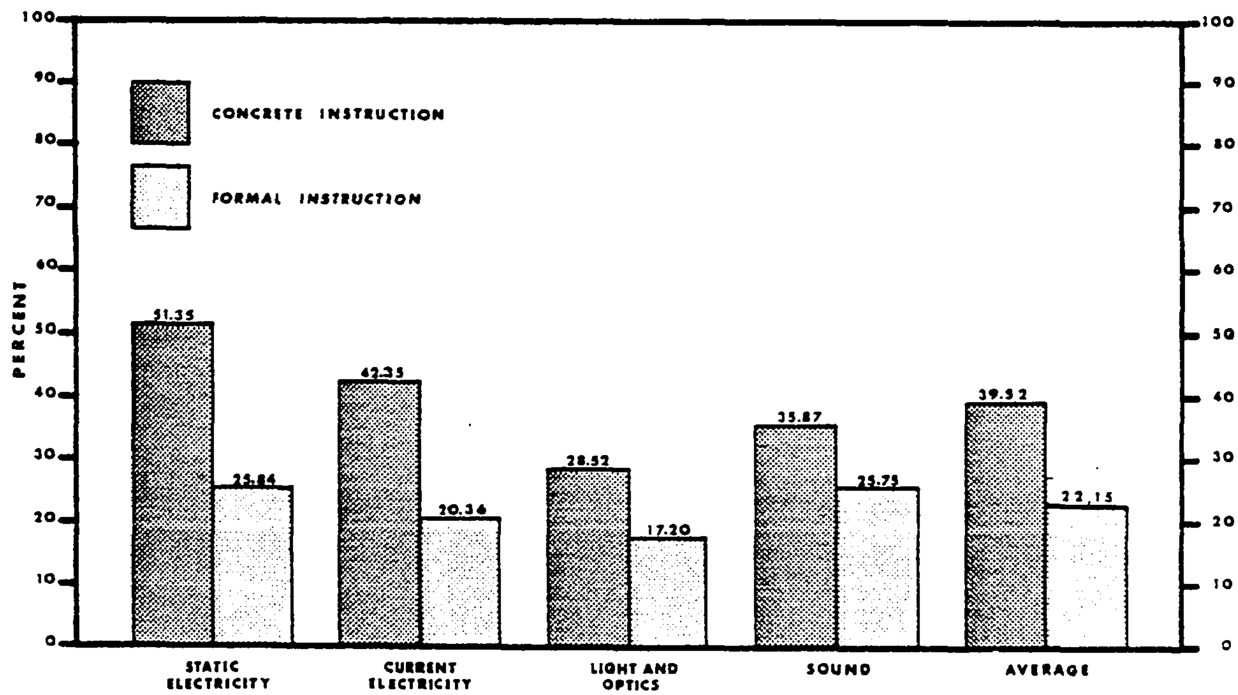


FIGURE 4-4
CONTENT POST-EXAMINATION MEANS, FREE RESPONSE



The means were all greater for the group experiencing concrete instruction. The means of the concrete instruction group, with the exception of the free response Light & Optics and Sound post-examinations, were significantly greater at the 0.0005 level than the means of the formal instruction group. The difference between the means of the free response Light & Optics post-examination was significant at the 0.05 level.

An analysis of covariance was performed to determine whether the students' intellectual development level or I.Q. was responsible for the observed difference in means of the two instructional groups. The students' score on the intellectual development and I.Q. posttests were used for this analysis as they were the most recent measures.

Results of the analysis of covariance for the Static Electricity content post-examinations are presented in Tables 4-20 and 4-21.

TABLE 4-20

ANALYSIS OF COVARIANCE, PIAGETIAN POSTTEST AND STATIC ELECTRICITY POST-EXAMINATIONS

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	8398.82	
	Within	45	345.96	24.277
Free Response	Between	1	6976.14	
	Within	45	388.20	17.970

TABLE 4-21

ANALYSIS OF COVARIANCE, I.Q. POSTTEST AND STATIC ELECTRICITY, POST-EXAMINATIONS

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	7940.51	
	Within	45	302.37	26.261
Free Response	Between	1	6673.44	
	Within	45	335.39	19.898

The obtained F-ratios were all greater than the 7.24 required for significance at the 0.01 level for 1 and 45 degrees of freedom. The conclusion was drawn that neither intellectual development nor I.Q. differences were responsible for the observed difference between the means of the concrete instruction group and the formal instruction group. Null hypothesis four was rejected at the 0.0005 level of significance for both the multiple choice and the free response post-examinations in favor of the concrete instruction group.

Results of the analysis of covariance for the Current Electricity post-examinations are presented in Tables 4-22 and 4-23.
The obtained F-ratios were all greater than the 7.24 required for significance at the 0.01 level for 1 and 45 degrees of freedom. The conclusion was drawn that neither intellectual development nor I.Q. differences were responsible for the observed difference between the means of the concrete instruction group and the formal instruction group. Null hypothesis four was rejected at the 0.0005 level for both the

TABLE 4-22

ANALYSIS OF COVARIANCE, PIAGETIAN POSTTEST AND CURRENT ELECTRICITY POST-EXAMINATION

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	3518.37	
	Within	45	327.81	24.632
Free Response	Between	1	5226.99	
	Within	45	212.21	24.632

TABLE 4-23

ANALYSIS OF COVARIANCE, I.Q. POSTTEST AND CURRENT ELECTRICITY POST-EXAMINATION

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	3449.17	
	Within	45	322.91	10.682

multiple choice and the free response post-examinations in favor of the concrete instruction group.

Results of the analysis of covariance for the Light & Optics post-examinations are presented in Tables 4-24 and 4-25.

The obtained F-ratios were all greater than the 7.24 required for significance at the 0.01 level for 1 and 45 degrees of freedom. The conclusion was drawn that neither intellectual development nor I.Q. differences were responsible for the observed difference between the means of the concrete instruction group and the formal instruction group.

TABLE 4-24

ANALYSIS OF COVARIANCE, PIAGETIAN POSTTEST
AND LIGHT AND OPTICS POST-EXAMINATION

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	3361.26	
	Within	45	176.74	10.018
Free Response	Between	1	1600.00	
	Within	45	163.80	9.768

TABLE 4-25

ANALYSIS OF COVARIANCE, I.Q. POSTTEST
AND LIGHT AND OPTICS POST-EXAMINATION

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	3239.48	
	Within	45	169.93	19.063
Free Response	Between	1	1394.06	
	Within	45	158.64	8.787

Null hypothesis four was rejected at the 0.0005 level for both the multiple choice and the free response post-examinations in favor of the concrete instruction group.

Results of the analysis of covariance for the Sound post-examinations are presented in Tables 4-26 and 4-27. The obtained F-ratios for the intellectual development posttest and multiple choice post-examination, I.Q. posttest and multiple choice post-examination and I.Q. posttest and

TABLE 4-26

ANALYSIS OF COVARIANCE, PIAGETIAN POSTTEST AND SOUND POST-EXAMINATION

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	5808.59	
	Within	44	412.84	14.070
Free Response	Between	1	1122.31	
	Within	44	406.97	2.758

TABLE 4-27

ANALYSIS OF COVARIANCE, I.Q. POSTTEST AND SOUND POST-EXAMINATION

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	5829.20	
	Within	44	411.73	14.158
Free Response	Between	1	5279.79	
	Within	44	218.87	24.123

free response post-examinations were all greater than the 7.24 required for significance at the 0.01 level. The F-ratio of 2.758 obtained for the intellectual development posttest and the free response post-examination was less than the 4.06 required for significance at the 0.05 level. The indication was that intellectual development was responsible for the difference between the means for the free response examination. Null hypothesis four was rejected at the 0.0005 level of significance for the multiple choice post-examination and with the above reservation rejected at the 0.05 level of significance for the free response post-examination.

Results of the analysis of covariance for the overall average post-examinations are presented in Tables 4-28 and 4-29.

TABLE 4-28

ANALYSIS OF COVARIANCE, PIAGETIAN POSTTEST AND OVERALL AVERAGE POST-EXAMINATION

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	5104.33	
	Within	45	160.19	31.864
Free Response	Between	1	3357.89	
	Within	45	125.32	26.794

TABLE 4-29

ANALYSIS OF COVARIANCE, I.Q. POSTTEST AND OVERALL AVERAGE POST-EXAMINATION

Content Examination	Source of Variation	df.	Variance Estimates	F
Multiple Choice	Between	1	4962.06	
	Within	45	153.81	32.262
Free Response	Between	1	3240.65	
	Within	45	111.74	29.002

The obtained F-ratios were all greater than the 7.24 required for significance at the 0.01 level for 1 and 45 degrees of freedom. The conclusion was drawn that neither intellectual development nor I.Q. differences were responsible for the observed difference between the means of the concrete instruction group and the formal instruction group. Null hypothesis four was rejected at the 0.0005 level of significance for both the multiple choice and the free response post-examinations in favor of the concrete instruction group.

Comparison of Content Examinations and Content Post-Examinations

In addition to the tests of hypotheses one and four a comparison was made between the results of scores for each content examination and content post-examination. Table 4-30 presents the raw data for content examination and content post-examination scores for each of the four content areas and the overall average for the multiple choice examinations. Table 4-31 presents similar raw data for the free response examinations. Table 4-32 presents the means, standard deviations, t-Ratios and significance levels for the multiple choice examinations and post-examinations for Static Electricity, Current Electricity, Light & Optics, Sound and the Overall Average of these four content examinations. Table 4-33 presents similar data for the free response examinations and post-examinations. For the purpose of this comparison data in parentheses are not included as a missing score makes it invalid. Figure 4-5 shows the content examination means and the content post-examination means.

The data for Static Electricity showed that the concrete instruction group increased from examination to post-examination, while the formal

TABLE 4-30

RAW DATA FOR CONTENT EXAMINATIONS
AND CONTENT POST-EXAMINATIONS - MULTIPLE CHOICE

Student	Sta. Elec.		Cur. Elec.		L & O		Sound		Overall Average	
Number	Ex	PEx	Ex	PEx	Ex	PEx	Ex	PEx	Ex	PEx
1	23	25	50	40	35	20	32	36	35.00	30.25
2	40	28	50	60	50	20	40	29	45.00	34.25
3	56	45	40	5	40	10	47	0	45.75	15.00
4	20	18	55	0	20	10	61	14	39.00	10.50
5	25	20	55	20	20	33	43	47	35.75	30.00
6	28	20	27	10	30	10	29	29	28.50	17.25
7	31	38	45	50	40	40	36	33	38.00	40.25
8	28	20	50	30	20	10	43	47	35.25	26.75
9	48	63	60	50	60	20	86	71	63.50	51.00
10	*	(35)	55	43	40	25	47	57	(47.33)	(40.00)
11	35	25	45	50	30	35	54	71	41.00	45.25
12	43	23	60	0	15	0	43	0	40.25	5.75
13	10	53	50	40	50	30	69	54	44.75	44.25
14	51	65	50	80	70	70	57	33	57.00	62.00
15	33	18	57	20	60	20	26	43	44.00	25.25
16	28	35	50	40	20	5	33	0	32.75	20.00
17	40	85	60	30	40	30	57	33	49.25	44.50
18	56	33	45	30	15	15	47	0	40.75	19.50
19	*	(60)	70	60	50	30	57	43	(59.00)	(48.25)
20	35	38	50	27	5	20	29	14	29.75	24.75
21	48	43	60	50	40	55	44	61	48.00	52.25
22	0	28	55	30	35	10	64	14	38.50	20.50
23	15	15	7	20	30	25	29	71	20.25	32.75
24	*	(48)	*	(5)	35	0	43	43	(39.00)	(24.00)
25	43	0	40	20	0	0	43	0	31.50	5.00
26	33	0	*	(0)	0	0	86	0	(39.67)	(0.00)
27	*	(0)	17	0	40	10	29	0	(28.67)	(2.50)
28	60	0	20	17	0	0	47	0	31.75	4.25
29	59	58	10	40	35	35	47	33	37.75	41.50
30	30	0	30	15	25	10	26	0	27.75	6.25
31	23	0	0	50	0	20	43	14	16.50	21.00
32	46	0	55	30	40	20	47	29	47.00	19.75
33	43	15	30	40	25	25	40	4	34.50	21.00
34	8	0	0	0	0	0	20	0	9.25	0.00
35	55	0	10	20	10	0	71	29	36.50	12.25
36	28	33	0	0	5	0	7	0	10.00	8.25
37	40	60	10	20	55	10	54	14	39.75	26.00
38	26	0	15	7	20	0	19	43	20.00	12.50
39	40	0	0	10	30	0	33	4	25.75	3.50
40	38	0	30	40	10	0	(43)	*	(30.25)	(13.33)
41	38	0	10	20	10	0	40	0	24.50	5.00
42	48	0	17	0	20	0	57	7	35.50	1.75
43	23	10	22	20	33	0	61	47	34.75	19.25
44	31	0	22	0	30	10	50	0	33.25	2.50
45	60	0	28	40	35	0	71	0	48.50	10.00
46	60	0	15	10	35	15	76	29	46.50	13.50
47	28	3	10	10	25	10	57	11	30.00	8.50
48	*	(0)	*	(0)	0	0	0	0	(0.00)	(0.00)

*Indicates that the student was absent on the day of the examination.
Students No. 1-23 experienced Concrete Instruction.
Students No. 24-48 experienced Formal Instruction.
Data in parentheses were not used in calculations.

TABLE 4-31

RAW DATA FOR CONTENT EXAMINATIONS
AND CONTENT POST-EXAMINATIONS - FREE RESPONSE

Student	Sta. Elec.		Cur. Elec.		L & O		Sound		Overall	Average
Number	Ex	PEx	Ex	PEx	Ex	PEx	Ex	PEx	Ex	PEx
1	42	36	59	45	51	40	71	60	55.75	45.25
2	32	44	43	74	41	28	53	57	42.25	50.75
3	68	68	41	49	29	7	24	13	40.50	34.25
4	40	24	53	21	24	2	56	10	43.25	14.25
5	38	38	44	36	40	30	20	14	35.50	29.50
6	32	24	44	29	34	32	36	45	36.50	32.50
7	70	78	41	34	27	24	71	17	52.25	38.25
8	53	80	53	39	39	20	6	27	37.75	41.50
9	54	78	81	77	83	47	77	64	73.75	66.50
10	51	36	51	64	50	60	61	64	53.25	56.00
11	50	50	39	49	47	32	71	50	51.75	45.25
12	42	81	57	34	46	8	60	0	51.25	30.75
13	64	38	67	34	44	40	51	42	56.50	38.50
14	88	92	67	53	71	32	70	57	74.00	58.50
15	69	70	46	14	47	32	64	14	56.50	32.50
16	37	38	37	21	19	20	54	17	36.75	24.00
17	65	76	56	49	81	37	57	34	64.75	49.00
18	83	34	43	63	53	34	31	38	52.50	42.25
19	21	70	70	64	27	20	39	45	39.25	49.75
20	51	42	40	36	31	31	31	0	38.25	27.25
21	44	44	*	(39)	43	35	53	60	(46.67)	(44.50)
22	8	28	37	39	36	27	43	45	31.00	34.75
23	33	12	0	11	13	18	0	52	11.50	23.25
24	63	74	*	(29)	56	7	71	57	(63.33)	(41.75)
25	56	0	34	35	29	5	53	57	43.00	24.25
26	24	46	*	(20)	36	25	14	28	(24.67)	(29.75)
27	1	22	26	10	26	20	0	0	13.25	13.00
28	66	44	53	22	36	12	14	0	42.25	19.50
29	26	16	20	22	36	32	57	41	34.75	27.75
30	78	24	34	12	37	24	13	28	40.50	22.00
31	86	30	67	30	46	28	34	60	58.25	37.00
32	76	42	79	60	49	35	0	18	51.00	38.75
33	63	52	31	22	43	30	0	21	34.25	31.25
34	20	0	46	32	0	0	39	0	26.25	8.00
35	45	30	43	29	23	40	39	14	37.50	28.25
36	48	18	7	8	9	0	13	0	19.25	6.50
37	47	36	24	19	44	14	49	21	41.00	22.50
38	46	18	7	5	26	12	39	20	29.50	13.75
39	48	18	20	12	33	17	14	21	28.75	17.00
40	44	20	24	10	41	5	(50)	*	(39.75)	(11.67)
41	71	2	7	7	10	5	60	14	37.00	7.00
42	98	0	37	17	50	0	0	45	46.25	15.50
43	40	44	16	12	39	12	29	45	31.00	28.25
44	60	14	36	22	40	22	53	34	47.25	23.00
45	63	40	61	43	61	32	67	20	63.00	33.75
46	39	30	19	9	50	32	43	45	37.75	29.00
47	39	26	11	15	21	21	39	24	27.50	21.50
48	9	0	*	(7)	0	0	0	5	(3.00)	(3.00)

*Indicates that the student was absent on the day of the examination.
Students No. 1-23 experienced Concrete Instruction.
Students No. 24-48 experienced Formal Instruction.
Data in parentheses were not used in calculations.

TABLE 4-32

MEANS, STANDARD DEVIATIONS, t-RATIOS AND SIGNIFICANCE LEVELS FOR CONTENT EXAMINATIONS AND POST-EXAMINATIONS MULTIPLE CHOICE

Content	Exam.	Concrete Instruction Mean	S. Dev.	Formal Instruction Mean	S. Dev.	t	df.	p
Static	Exam.	33.00	14.82	39.09	14.16	1.378	42	>0.20
Elect.	P. Ex.	35.14	18.42	8.14	18.17	4.839	42	<0.001
Current	Exam.	49.83	12.62	17.77	13.90	8.108	44	<0.001
Elect.	P. Ex.	34.13	20.35	18.59	15.52	2.870	44	<0.01
Light &	Exam.	35.43	16.44	20.72	16.18	3.124	46	<0.01
Optics	P. Ex.	23.61	16.12	6.60	9.76	4.462	46	<0.001
Sound	Exam.	46.65	14.92	44.83	20.73	0.344	45	>0.20
	p. Ex.	34.78	23.48	13.79	16.40	3.735	45	<0.001
Overall	Exam.	40.75	9.58	31.05	11.08	2.947	39	<0.01
Average	P. Ex.	31.05	14.88	12.09	10.20	4.735	39	<0.001

TABLE 4-33

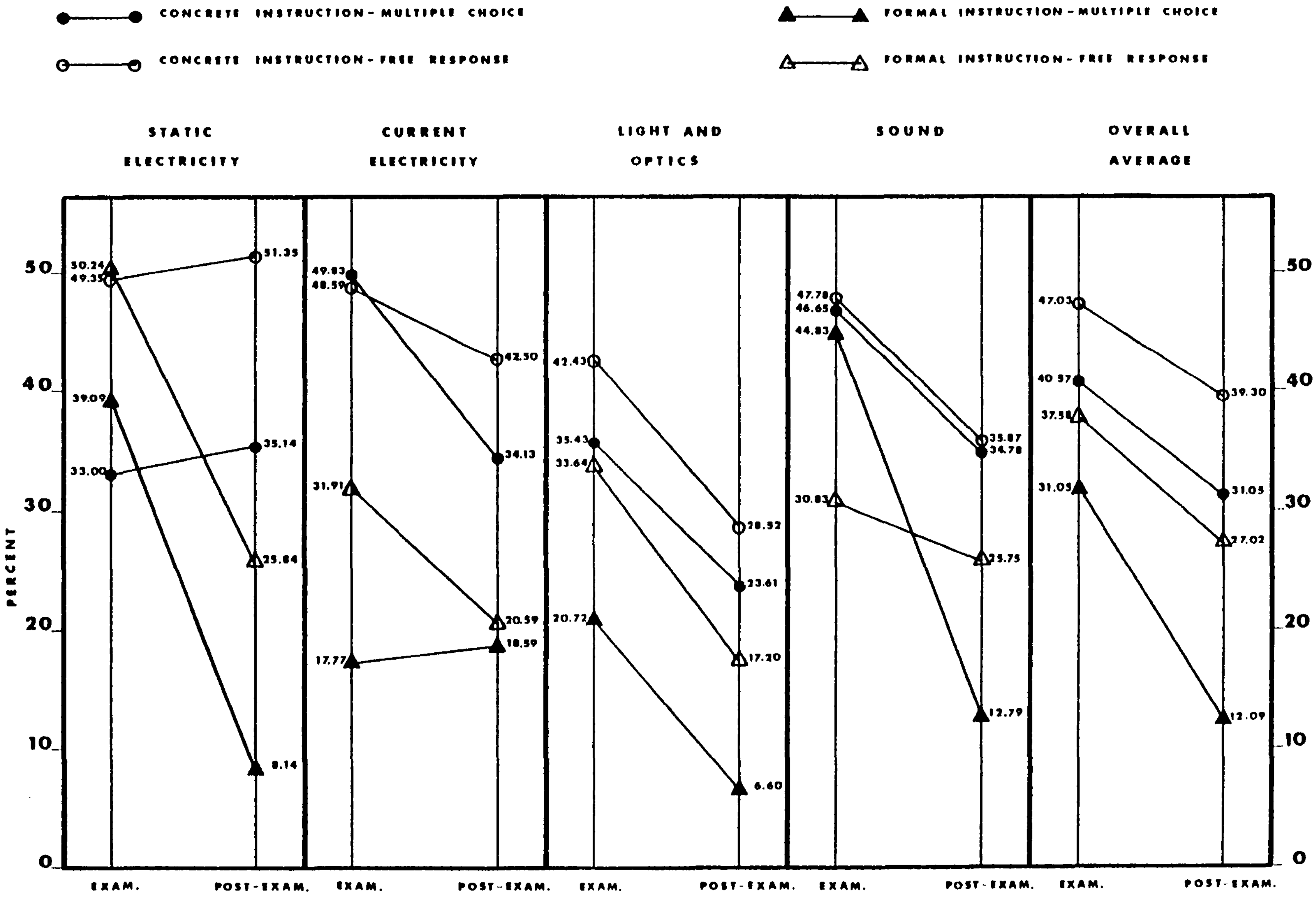
MEANS, STANDARD DEVIATIONS, t-RATIOS AND SIGNIFICANCE LEVELS FOR CONTENT EXAMINATIONS AND POST-EXAMINATIONS FREE RESPONSE

Content	Exam.	Concrete Instruction Mean	S. Dev.	Formal Instruction Mean	S. Dev.	t	df.	p
Static	Exam.	49.35	19.28	50.24	23.34	0.144	46	>0.20
Elect.	P. Ex.	51.35	22.81	25.84	18.71	4.250	46	<0.001
Current	Exam.	48.59	16.16	31.91	19.85	3.056	42	<0.01
Elect.	P. Ex.	42.50	18.27	20.59	13.40	4.535	42	<0.001
Light &	Exam.	42.43	17.74	33.64	16.28	1.791	46	<0.10
Optics	P. Ex.	28.52	13.03	17.20	12.50	3.071	46	<0.01
Sound	Exam.	47.78	21.29	30.83	23.25	2.603	45	<0.02
	P. Ex.	35.87	21.22	25.75	18.77	1.733	45	<0.10
Overall	Exam.	47.03	14.34	37.58	11.95	2.341	40	<0.05
Average	P. Ex.	39.30	12.69	27.02	23.18	2.167	40	<0.05

FIGURE 4-5

CONTENT EXAMINATION AND

CONTENT POST EXAMINATION MEANS



instruction group decreased. The increase of the concrete instruction group on the free response examination (49.35 to 51.35) represents a change of just less than the formal instruction group examination mean (50.24) to just greater than the formal instruction group examination mean. A similar increase occured with the multiple choice examinations. The increase of the concrete instruction group (33.00 to 35.14) is close to the formal instruction group examination mean (30.09).

A possible explanation as to why the observed increase in content-achievement occured with the concrete instruction group is offered. The content material immediately following Static Electricity was Current Electricity. The possibility existed that the interaction with the Static Electricity materials and apparatus was not sufficient to allow the building of mental structures required to function with the concepts of Static Electricity. However the additional interaction and experiences with the closely related topic of Current Electricity provided sufficient experience to allow the students to accomodate and thereby build those structures which allowed them to exhibit greater content-achievement when writing the content post-examinations.

The data for Current Electricity showed both the concrete instruction group and the formal instruction group decreased in the means of content-achievement. The post-examination mean for the multiple choice examination of the concrete instrution group (34.13) was greater than the examination mean of the formal instruction group (31.91). Similarly the free response post-examination mean (42.50) was much greater than the examination mean for the formal instruction group (17.77). The data indicated the concrete instruction group not only showed significantly greater content-achievement gains during the instructional period but retained more after three months than the formal instruction group acquired during the instructional period with the formal instruction group losing a significant portion of acquired content-achievement.

The data for Light & Optics showed both the concrete instruction group and the formal instruction group decreased in the means of content-achievement. The multiple choice post-examination mean of the concrete instruction group (23.61) was greater than the examination mean of the formal instruction group (20.72). The free response post-examination mean of the concrete instruction group (23.61) was less than the examination mean of the formal instruction group (33.64). The data indicated that the concrete instruction group retained approximately the same level of content-achievement after three months as the formal instruction group had acquired during the instructional period with the formal instruction group losing a significant portion of acquired content-achievement.

The data for Sound showed both the concrete instruction group and the formal instruction group decreased in the means of content-achievement. The multiple choice post-examination mean of the concrete instruction group (34.78) was less than the examination mean of the formal instruction group (44.83). The free response post-examination mean of the concrete instruction group (35.87) was greater than the examination mean of the formal instruction group (30.83). The data indicated that the concrete instruction group retained approximately the same level of content-achievement after three months as the formal instruction group acquired during the instructional period with the formal instruction group losing a significant portion of acquired content-achievement.

The data for the overall average content-achievement scores showed both the concrete instruction group and the formal instruction group decreased in the means of content-achievement. The multiple choice post-examination mean of the concrete instruction group (31.05) was the same as the examination mean of the formal instruction group. The free response post-examination mean of the concrete instruction group (30.30) was greater than the examination mean of the formal instruction group (37.58). The data indicated that the concrete instruction group retained more content-achievement after three months than the formal instruction group acquired during the instructional period with the formal instruction group exhibiting a marked decrease in content-achievement.

CHAPTER V

GROUP DIFFERENCES IN INTELLECTUAL DEVELOPMENT AND I.Q.

Intellectual Development

Hypothesis two was tested to determine the effect of teaching method on intellectual development gains made by the students during the experimental procedure. Hypothesis five was tested to determine the effect of teaching method on the retention of gains made in intellectual development three months after the conclusion of the experimental portion of the study and may be thought of as an extension of hypothesis two. Table 5-1 presents the raw data for the Piagetian tasks used to measure intellectual development. Student number forty was not available for post-posttesting and therefore was removed from the sample for the purpose of testing hypotheses two and five. Table 5-2 presents the students' Piagetian total scores for pretest, posttest and post-posttest and pretest to posttest, posttest to post-posttest and pretest to post-posttest difference scores. Table 5-3 presents the means, standard deviations, t-ratios and significance levels for the total scores of the Piagetian measures of intellectual development.

For each case the t-ratio was less than the 0.851 required for significance at the 0.20 level. The t-ratio tests results were misleading, however. Figure 5-1 presents the means of the total scores for the

TABLE 5-1

RAW DATA FOR PIAGETIAN TASKS

Student Number	Pretest Con. Vol.	Pretest Sep. Var.	Pretest Equ. Bal.	Pretest Col. Liq.	Posttest Con. Vol.	Posttest Sep. Var.	Posttest Equ. Bal.	Posttest Col. Liq.	Post-postest Con. Vol.	Post-postest Sep. Var.	Post-postest Equ. Bal.	Post-postest Col. Liq.
1	1	1	1	1	2	2	1	2	1	2	1	2
2	3	2	1	2	3	2	1	2	3	1	1	2
3	3	2	1	2	3	4	3	2	3	3	3	2
4	1	1	1	1	1	2	2	2	1	2	2	2
5	1	2	1	2	1	1	1	2	1	3	1	2
6	1	2	1	2	3	2	1	1	3	2	2	2
7	3	2	2	3	3	3	3	2	3	3	3	2
8	3	2	1	2	3	2	3	2	3	3	3	2
9	3	3	2	4	3	4	2	2	3	4	3	4
10	1	2	1	2	1	2	2	2	2	3	2	2
11	1	2	1	2	1	3	2	2	1	3	1	2
12	3	1	1	2	3	3	3	2	3	3	2	2
13	2	2	2	2	3	3	2	2	3	3	3	2
14	2	2	1	2	3	3	2	2	3	2	1	3
15	3	2	2	1	3	3	2	2	3	3	3	2
16	3	2	1	2	1	3	1	2	2	2	2	2
17	1	1	1	1	1	1	1	1	3	2	3	2
18	2	2	2	2	3	2	2	2	3	2	3	2
19	3	2	2	2	3	3	2	3	3	3	3	3
20	1	1	1	1	1	1	1	1	1	2	1	2
21	3	3	1	2	3	3	3	2	3	3	3	3
22	3	1	1	2	3	3	1	3	3	3	1	2
23	1	1	1	1	1	1	1	1	1	1	1	2
24	2	2	1	2	3	3	1	3	3	3	1	3
25	2	3	3	2	2	3	3	2	3	4	3	3
26	3	2	2	3	3	3	2	3	2	3	2	2
27	1	1	1	1	1	2	2	2	1	2	2	2
28	3	2	3	2	3	4	3	2	3	4	3	2
29	2	2	1	2	3	3	2	2	3	2	1	2
30	2	2	1	1	2	2	1	2	1	3	2	2
31	3	2	1	2	3	2	1	2	3	2	1	2
32	3	3	2	2	3	3	3	3	3	4	3	2
33	1	2	1	2	2	2	1	2	3	2	1	2
34	3	2	1	2	3	2	3	3	3	3	3	2
35	1	1	1	1	2	1	1	2	2	3	2	1
36	3	2	2	2	3	2	2	2	3	3	2	2
37	1	2	2	1	2	2	2	2	1	2	2	2
38	1	1	1	2	1	1	1	2	2	1	1	2
39	2	1	1	1	3	1	1	2	3	2	1	2
40	2	2	1	2	3	2	2	2	*	*	*	*
41	3	2	1	1	1	1	1	2	3	2	1	2
42	2	3	1	2	3	3	3	2	3	3	3	3
43	3	2	1	2	1	2	1	1	3	3	2	2
44	2	2	1	2	2	3	1	2	2	2	1	2
45	3	2	1	2	1	2	1	2	3	3	2	3
46	2	2	1	2	1	2	1	2	3	2	1	2
47	1	1	1	2	1	2	1	2	1	2	1	2
48	3	1	3	2	1	1	1	1	1	1	1	1

*Indicates that student was not available for testing.
Students No. 1-23 experienced Concrete Instruction.
Students No. 24-48 experienced Formal Instruction.

TABLE 5-2

PIAGETIAN TOTAL SCORES AND CHANGE OF SCORES

Student	Pretest	Posttest	Post-Posttest	Pretest to Post-posttest	Posttest to Post-posttest	Pretest to Post-posttest
1	4	7	6	+3	-1	+2
2	8	8	7	0	-1	-1
3	8	12	11	+4	-1	+3
4	4	7	7	+3	0	+3
5	6	5	7	-1	+2	+1
6	6	7	9	+1	+2	+3
7	10	11	11	+1	0	+1
8	8	10	11	+2	+1	+3
9	12	11	14	-1	+3	+2
10	6	7	9	+1	+2	+3
11	6	8	7	+2	-1	+1
12	7	11	10	+4	-1	+3
13	8	10	11	+2	+1	+3
14	7	10	9	+3	-1	+2
15	8	10	11	+2	+1	+3
16	8	7	8	-1	+1	0
17	4	4	10	0	+6	+6
18	8	9	10	+1	+1	+2
19	9	11	12	+2	+1	+3
20	4	4	6	0	+2	+2
21	9	11	12	+2	+1	+3
22	7	10	9	+3	-1	+2
23	4	4	5	0	+1	+1
24	7	10	10	+3	0	+3
25	10	10	13	0	+3	+3
26	10	11	9	+1	-2	-1
27	4	7	7	+3	0	+3
28	10	12	12	+2	0	+2
29	7	10	8	+3	-2	+1
30	6	7	8	+1	+1	+2
31	8	8	8	0	0	0
32	10	12	12	+2	0	+2
33	6	7	8	+1	+1	+2
34	8	11	11	+3	0	+3
35	4	6	8	+2	+2	+4
36	9	9	10	0	+1	+1
37	6	8	7	+2	-1	+1
38	5	5	6	0	+1	+1
39	5	7	8	+2	+1	+3
40	(7)	(9)	*	(+2)	*	*
41	7	5	8	-2	+3	+1
42	8	11	12	+3	+1	+4
43	8	5	10	-3	+5	+2
44	7	8	7	+1	-1	0
45	8	6	11	-2	+5	+3
46	7	6	8	-1	+2	+1
47	5	6	6	+1	0	+1
48	9	4	4	-5	0	-5

*Indicates Student absent, data in parentheses not used.
Students No. 1-23 experienced Concrete Instruction.
Students No. 24-48 experienced Formal Instruction.

FIGURE 5-1

INTELLECTUAL DEVELOPMENT MEANS

PRETEST, POSTTEST AND POST-POSTTEST

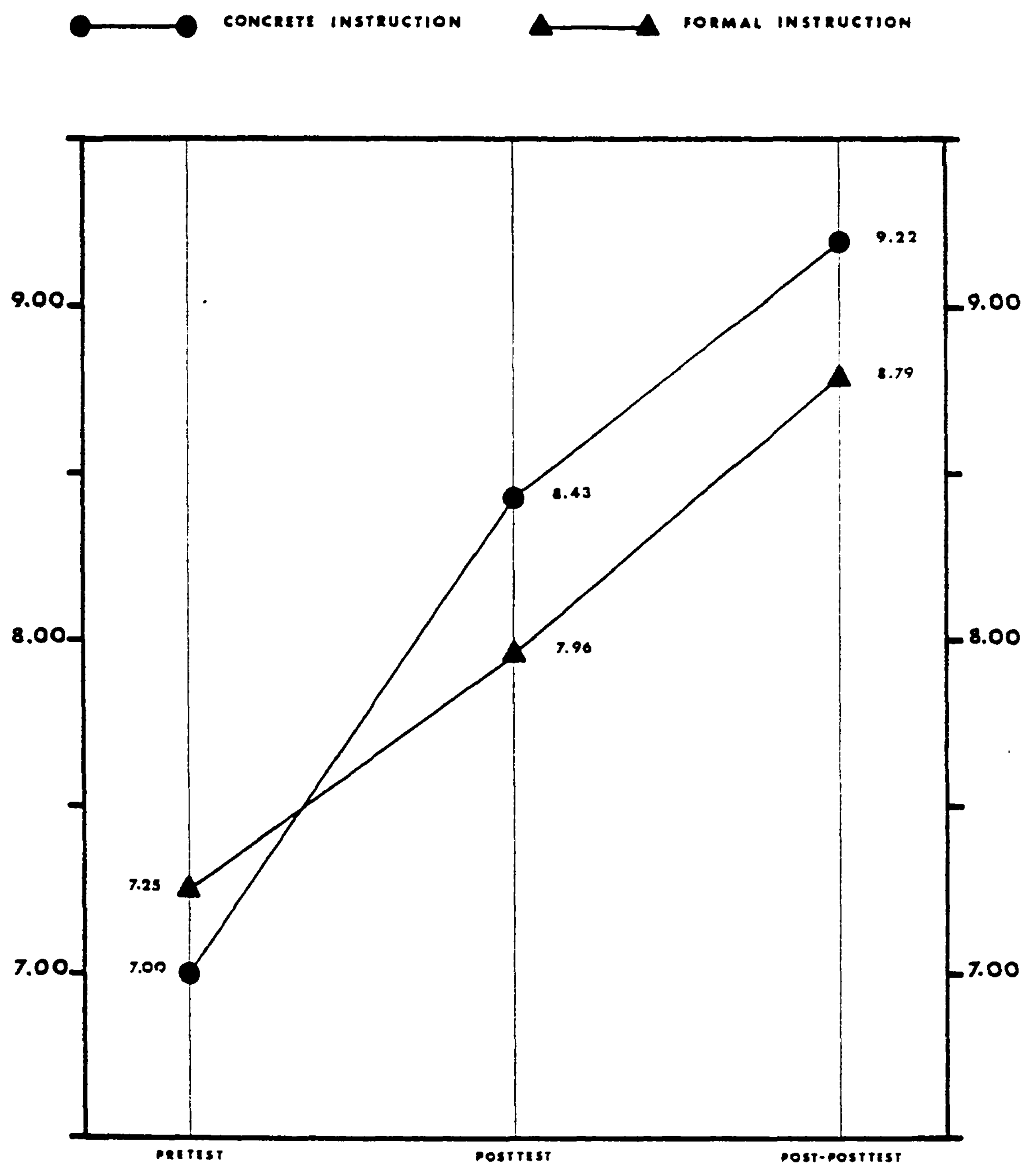


TABLE 5-3

MEANS, STANDARD DEVIATIONS, t-RATIOS AND SIGNIFICANCE LEVELS FOR PIAGETIAN PRETEST, POSTTEST AND POST-POSTTEST

	Concrete Instruction		Formal Instruction				
	Mean	S. Dev.	Mean	S. Dev.	t	df.	p
Pretest	7.00	2.11	7.25	1.87	0.430	46	>0.20
Posttest	8.43	2.52	7.96	2.42	0.661	46	>0.20
Post-posttest	9.22	2.30	8.79	2.25	0.643	46	>0.20

Piagetian pretest, posttest and post-posttest. The lines of the concrete instruction and the formal instruction group cross during the instructional period. The slope of the intellectual development line for the group experiencing concrete instruction was greater than the slope for the group experiencing formal instruction. The concrete instruction group mean was slightly less than the formal instruction group mean at the onset of the study and slightly greater than the formal instruction group mean at the conclusion of the experimental portion of the study. The Piagetian total difference scores were tested for significance using the t-statistic. Results of the test are presented in Table 5-4.

The calculated t-Ratio for the Piagetian total difference scores from pretest to posttest of 1.352 was significant at the 0.10 level. The data indicated that the concrete instruction group exhibited greater gains in intellectual development than the formal instruction group as measured by the Piagetian tasks. Hypothesis two was rejected at the 0.10 level of significance in favor of the concrete instruction group.

During the three month interim between posttest and post-posttest all students were returned to their regular science classes. These

TABLE 5-4

DIFFERENCE TOTAL PIAGETIAN SCORE MEANS, STANDARD DEVIATIONS, t-RATIOS AND SIGNIFICANCE LEVELS

	Concrete Instruction		Formal Instruction				
	Mean	S. Dev.	Mean	S. Dev.	t	df.	p
Pretest to Posttest	1.43	1.53	0.71	2.10	1.352	46	<0.10
Posttest to Post-Posttest	0.78	1.68	0.83	1.81	0.100	46	>0.20
Pretest to Post-posttest	2.22	1.38	1.54	1.89	1.396	46	<0.10

classes were taught by the same teacher who was aware of the design of this study and made every effort to give both groups the same instruction both in terms of content and methodology. That methodology included a blend of concrete instruction and formal instruction. The students were asked to do some laboratory work and also received lectures from the instructor. The slopes of the increases in intellectual development means were identical, each experimental group showed increases in intellectual development at the same rate. The calculated t-Ratio for Piagetian total difference scores from posttest to post-posttest of 0.100 was not significant at the 0.20 level of significance. The data indicated that after the students were returned to their regular science classes the intellectual development gains for both groups of students increased at parallel rates.

The t-Ratio was calculated between the Piagetian total difference scores from pretest to post-posttest. The obtained 1.396 was significant at the 0.10 level. Those data indicated the concrete instruction group retained the increased gains in intellectual development they had made over the formal instruction group during the experimental portion of the study. Hypothesis five was rejected in favor of the concrete instruction group at the 0.10 level of significance.

The data indicated that the concrete instruction group exhibited greater gains in intellectual development than the formal instruction group during the instructional period. The reader should keep in mind this trend was established with each student experiencing only one hour per day of his instruction methodology for eighty days. That eighty days was further reduced by the administration of content examinations (6 days), I.Q. examinations (2 days) and interuptions such as assemblies (4 days) to leave sixty eight days instruction time. The remainder of the school day for each student was randomly determined according to class scheduling possibilities and was similar for students in both groups. The data indicated that concrete instruction leads to increased gains in intellectual development.

Learner I.Q.

Hypothesis three was tested to determine the effect of instruction method on learner I.Q. gains made during the experimental procedure. The students' sex, age at the onset of the study and raw data for the students' I.Q. for pretest and posttest are presented in Table 5-5. Table 5-6 presents the means, standard deviations, t-Ratios and significance levels for pretest and posttest I.Q. Figure 5-2 shows the means of each instruction group for I.Q. language, non language and overall score.

TABLE 5-5

STUDENTS SEX, AGE AT ONSET OF STUDY AND RAW DATA FOR I.Q.

Student Number	Age in Months	Sex	Pretest Lang.	Pretest Non-Lang.	Pretest Over-all	Posttest Lang.	Posttest Non-Lang.	Posttest Over-all
1	171	F	100	110	105	102	94	99
2	175	M	85	93	89	90	105	98
3	177	M	109	117	114	99	109	103
4	173	M	92	88	89	97	101	100
5	171	F	99	99	100	92	116	102
6	179	F	107	95	101	108	89	99
7	177	M	98	112	105	94	115	102
8	169	M	91	106	99	97	101	100
9	172	F	105	118	110	117	117	119
10	175	M	96	84	89	96	92	94
11	177	M	95	87	90	89	99	94
12	176	M	85	108	97	94	112	102
13	174	F	95	98	97	104	105	105
14	170	F	110	110	111	120	117	121
15	172	F	88	115	101	92	113	102
16	176	F	89	82	87	86	96	91
17	168	M	122	106	117	125	118	125
18	176	M	79	91	94	80	93	87
19	176	M	94	93	94	91	94	93
20	180	F	80	87	82	83	118	98
21	156	M	105	120	111	97	139	110
22	155	M	86	112	100	105	119	111
23	180	F	84	84	82	77	60	65
24	171	F	116	122	119	111	102	108
25	174	F	88	104	97	101	103	103
26	175	F	101	106	104	108	99	105
27	166	F	84	87	83	98	87	92
28	175	M	102	111	106	111	116	113
29	173	F	100	98	100	92	92	92
30	176	F	115	104	111	116	99	109
31	179	M	84	90	87	92	88	89
32	172	M	119	109	116	117	100	110
33	169	F	89	101	96	99	106	103
34	173	M	93	101	98	83	98	91
35	195	F	91	111	99	90	104	96
36	170	F	91	96	94	105	106	107
37	170	F	110	110	111	104	111	107
38	171	F	100	85	92	85	82	82
39	168	F	97	78	86	106	90	98
40	176	F	102	98	101	97	102	100
41	174	F	93	99	97	95	107	101
42	171	M	106	103	106	107	97	103
43	174	F	91	79	83	83	91	86
44	169	F	98	102	101	106	114	109
45	178	F	92	107	100	98	118	105
46	171	F	96	94	95	101	102	102
47	181	F	89	93	91	97	90	94
48	177	M	87	82	82	71	69	66

Students No. 1-23 experienced Concrete Instruction.
Students No. 24-48 experienced Formal Instruction.

FIGURE 5-2

I. Q. MEANS

TEST AND POSTTEST

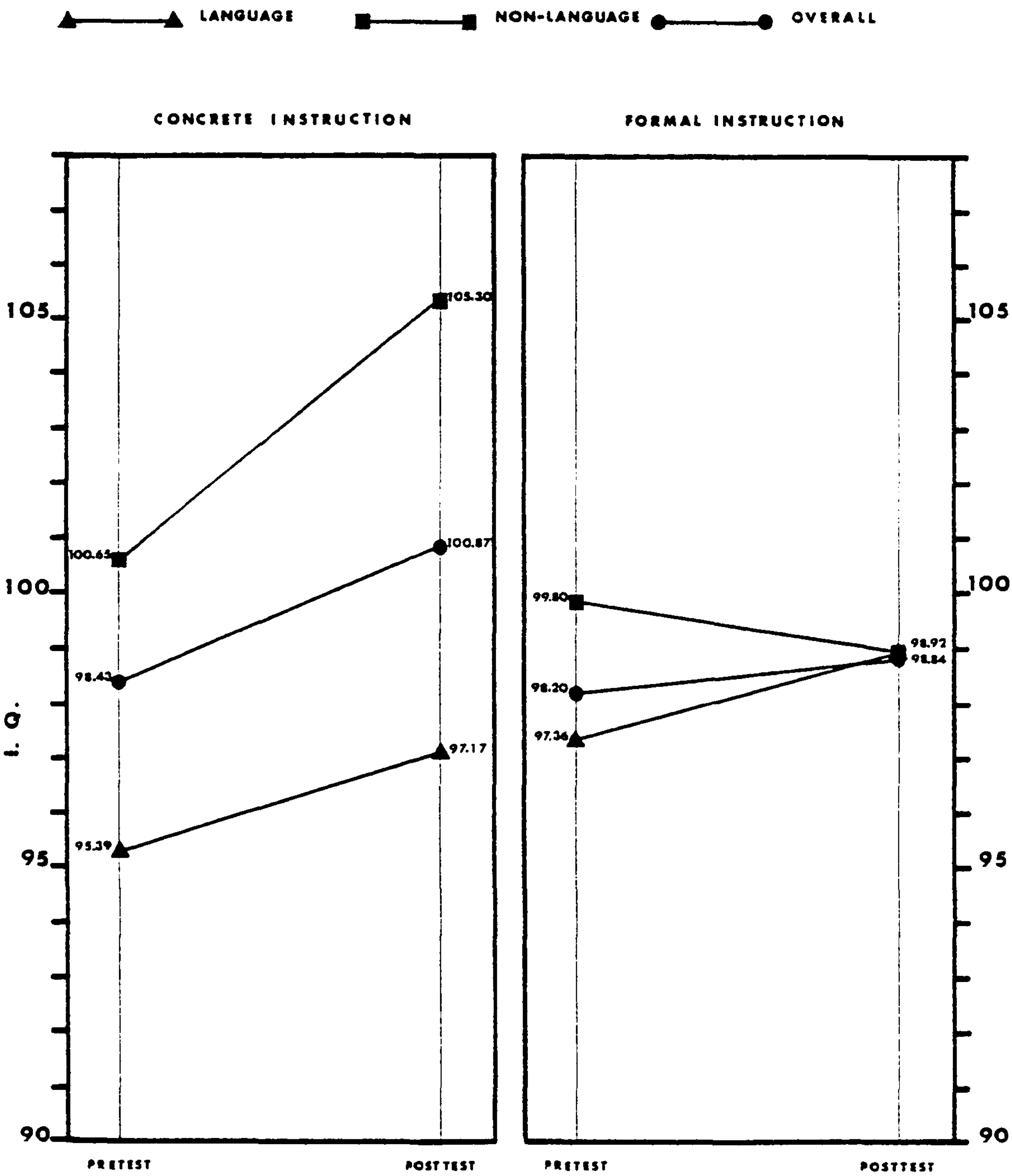


TABLE 5-6

MEANS, STANDARD DEVIATIONS, t-RATIOS AND SIGNIFICANCE LEVELS FOR I.Q. PRESTEST AND POSTTEST

	Concrete Instruction		Formal Instruction				
	Mean	S. Dev.	Mean	S. Dev.	t	df.	p
I.Q. Pretest							
Language	95.39	10.74	97.36	9.82	0.664	46	>0.20
Non-Language	100.65	12.39	99.80	10.91	0.551	46	>0.20
Overall	98.43	9.99	98.20	9.96	0.081	46	>0.20
I.Q. Posttest							
Language	97.17	12.06	98.92	11.01	0.524	46	>0.20
Non-Language	105.30	15.54	98.92	11.15	1.646	46	<0.10
Overall	100.87	12.22	98.84	10.61	0.616	46	>0.20

The obtained t-Ratios were all less than that required for significance at the 0.20 level for the I.Q. pretest. The data indicated that no significant difference between the I.Q. levels of the two groups existed at the onset of the study.

The obtained t-Ratios for the Language and overall scores of the I.Q. posttest were both less than that required for significance at the 0.20 level. The non-language t-Ratio for the I.Q. posttest was greater than the 1.303 required for significance at the 0.10 level.

The t-Ratios were then calculated for the difference scores between the I.Q. pretest and posttest for language, non-language and overall scores. The results of the t-tests are presented in Table 5-7.

The obtained t-Ratios for the Language and Overall difference scores between pretest and posttest were less than that required for significance

TABLE 5-7

CHANGE IN I.Q. SCORE FROM PRETEST TO POSTTEST MEANS, STANDARD DEVIATIONS, t-RATIOS AND SIGNIFICANCE LEVELS

	Concrete Instruction Mean	S. Dev.	Formal Instruction Mean	S. Dev.	t	df.	p
Language	1.78	7.24	1.56	8.83	0.095	46	>0.20
Non-Language	4.65	11.90	0.60	8.46	1.369	46	<0.10
Overall	2.39	7.79	0.64	7.53	0.792	46	>0.20

at the 0.20 level. The difference scores for the non-language I.Q. score between pretest and posttest yielded a t-Ratio greater than the 1.303 required for significance at the 0.10 level.

The data indicated that concrete instruction and formal instruction did not differ in their effect on the learners' language I.Q., nor their overall I.Q. The data indicated that concrete instruction was more effective than formal instruction for the increase of the learners non-language I.Q. Hypothesis three was accepted for the learners language I.Q. and overall I.Q. Hypothesis three was rejected for the learners non-language I.Q. in favor of the concrete instruction group at the 0.10 level.

A possible criticism may be directed toward the nature of the measurement of intellectual development. Intellectual development was measured using Piagetian tasks which involved the direct interaction between the student and laboratory apparatus. The concrete instruction methodology extensively utilized the interaction of the student with laboratory apparatus while the formal instruction methodology presented a void of such interaction. The argument may be advanced that a student experiencing concrete instruction is merely trained to function at a higher level with the Piagetian task apparatus than a student experiencing formal instruction who lacks that training. This argument is substantially weakened by the results of the paper and pencil I.Q. examinations. The concrete instruction group showed significantly greater non-language I.Q. development than the formal instruction group. The data indicated that concrete instruction leads to greater mental development whether measured by apparatus centered or paper and pencil methods of evaluation.

CHAPTER VI

RESULTS OF THE ATTITUDE QUESTIONNAIRE

On the last day of instruction both the concrete instruction and the formal instruction groups were asked to complete a "Student Evaluation of the Course". (See Appendix D.) The students were instructed not to put their names on the questionnaire and to answer as honestly as they could. The students were not allowed to discuss their responses with other students while filling out the questionnaire.

Items one, two and three state: "How would you classify the primary teaching procedures used in this course? (Check as many as applicable but if you check more than one, please rank your answers as 1, 2, 3, etc. in order from most frequently used to least frequently used.)" The results of the responses were then tabulated using the first three choices of each student and the results are reported in Table 6-1.

The concept of instructional procedure exhibited by the concrete instruction group followed closely the definition of concrete instruction utilized for the design of the study. Two apparent anomalies were expressed, however. The concrete instruction group chose "Teacher demonstration without extensive lecture" most frequently as their first choice of instructional procedure, and "Materials (apparatus)

TABLE 6-1

RANKED RESPONSES TO ITEM ONE OF THE ATTITUDE QUESTIONNAIRE

Response Selection	Concrete Instruction 1st	2nd	3rd	Formal Instruction 1st	2nd	3rd
Lecture	0	1	1	9	0	0
Small Group Discussion	2	2	2	2	1	2
Large Group Discussion	1	1	1	0	2	1
Laboratory Group Work	5	0	3	1	2	1
Lecture-Demonstration	1	2	0	3	2	0
Teacher demonstration without extensive Lecture	11	2	0	1	2	3
Materials (apparatus) centered teaching	0	1	0	0	0	0
Working alone in the laboratory	2	0	1	0	0	1
Instructor working sample problems	0	1	1	0	6	2
Instructor working with individuals and small groups	4	4	2	1	0	0
Instructor telling the students what they should know	2	0	1	4	1	2
Instructor assisting the students in learning the concept	6	4	3	1	0	2

centered teaching" as the least frequently used instructional method. Demonstrations were occasionally performed when the apparatus were not available in numbers great enough for class experimentation. During these demonstrations small groups of students would be shown the apparatus and allowed to manipulate it themselves. This procedure, however, was used in less than ten percent of the experiments. This investigator believes that the low response of the concrete instruction group to "Materials (apparatus) centered teaching" could be attributed to the students' misunderstanding of the statement. The concrete instruction group next most frequently selected as their first choice "Instructor assisting the students in learning the concept" followed by "Laboratory group work" and then by "Instructor working with individuals and small groups". The concrete instruction group selected most frequently as their second choice "Instructor working with individuals and small groups" and "Instructor assisting the students in learning the concept". These selections followed closely what has previously been defined as the concrete instruction model which was utilized in this study.

The formal instruction group chose "Lecture" followed by "Instructor telling the students what content they should know" and then "Lecture-Demonstration" as the primary instructional procedures used during the course. The most frequently selected second choice of the formal instruction group was "Instructor working sample problems". These selections followed the definition of formal instruction utilized for this study.

The data indicated that the students' view of the instructional procedures used was generally parallel with the design of each instructional method. The selection of the response "Teacher demonstration without extensive lecture" and avoidance of the response "Materials (apparatus) centered teaching" by the concrete instruction group raised the question of the validity of item one for ninth grade students.

Item four asked the students to select whether they felt they were being told what content material to know or whether they felt they were being led to find out about the content material. All twenty three students in the concrete instruction group responded; eight students selected the response which said they felt they were being told what content material to know, fifteen students selected the response which indicated they felt they were being led to find out about the content material. Only nineteen of the twenty five students in the formal instruction group responded; seven of those students felt they were being told what content material to know and twelve of the students felt they were being led to find out about the content material. The response of both groups to this item was similar and did not indicate a differentiation between instructional procedures. This investigator believes that the validity of item four for ninth grade students is questionable; the phrases "being led" and "being told" apparently have several meanings.

Item five asked the students to evaluate their feelings about the course. The responses were then ranked for both instruction groups and the results are presented in Table 6-2. The numbers in parentheses indicate the number of students responding to that selection.

The concrete instruction group indicated they liked the instructional procedure with only two students selecting a response indicating a dislike for the instructional procedure. The actions of the students during the instructional period confirmed this feeling as many students would be in class early in anticipation of the day's activity.

TABLE 6-2

RANKED RESPONSES FOR ITEM FIVE OF THE ATTITUDE QUESTIONNAIRE

Concrete Instruction Group

I liked them. (19)
I liked finding out ideas for myself. (13)
I liked them, but felt insecure for a few weeks. (6)
I liked being told what to do. (6)
I liked them, but felt insecure for the entire semester. (3)
I did not like them, because I felt insecure. (1)
I did not like them. (1)

Formal Instruction Group

I liked them. (11)
I liked them, but felt insecure for a few weeks. (7)
I did not like them. (6)
I liked finding out ideas for myself. (6)
I liked being told what to do. (3)
I did not like them, because I felt insecure. (2)
I liked them, but felt insecure for the entire semester. (0)

The formal instruction group indicated they liked the instructional procedure with a few feeling insecure for a few weeks. Several students in the formal instruction group, however, indicated they did not like the procedures. As previously mentioned in Chapter II, Chronology of the Study, the hostility evidenced by approximately one-third of the formal instruction group against writing the content post-examinations led to the early termination of the study. For this reason the content post-examinations for Magnetism and Electromagnetism were not given to the students. The students' hostilities were also evidenced through unsolicited written comments on the examination papers. One student, for example, stated that she refused to write any further examinations. The comments of these students corresponded with the selection of responses to item five. Approximately one-third of the students selected responses which demonstrated negative feelings about the course. As no names were associated with the attitude questionnaire the degree to which a correlation existed between the students responding negatively about their feelings of the course on the attitude questionnaire and those students writing negative comments on content post-examinatnion papers about taking the post-examinations was not possible. Highly critical students, although not the majority, were responsible for the early termination of the study. The remaining students in the formal instruction group were willing to continue the post-examinations and all of the concrete instruction group were willing to continue the content post-examinations.

Item six asked the students to write a few lines describing their feelings about the course. Specific responses may be found in Appendix C. In general the students in the concrete instruction group expressed good feelings about the course. A few of the formal instruction group felt they liked the course but many in the formal instruction group expressed a dislike for the course and for science. The negative feelings expressed by the students in the formal instruction group in response to item six reflected the same tenor as did the unsolicited feelings expressed on the content post-examination papers concerning the post-examinations. Clearly the formal instructional procedure had alienated many students (but less than half of the class) in the formal instruction group.

Item seven asked the students to indicate how much the instructor added or detracted to their feelings about the course. The students in the concrete instruction group generally were satisfied with the instructor. The students in the formal instruction group similarly were satisfied with the instructor. Specific responses to item seven may be found in Appendix C. The indication from responses to item seven was that the feelings of both groups toward the instructor were similar and positive.

Item eight asked the students to indicate what changes they would like to have made that would improve the course. Specific responses may be found in Appendix C, however, no suggestions were made that were found useful in improving the course. This investigator believes that ninth grade students are not able to evaluate a course and make critical statements about how to improve instructional methods.

Item nine asked the students to write a statement indicating either why they preferred a standard lecture course or why they preferred a course based on laboratory experience. Specific responses may be found in Appendix D. Four students in the concrete instruction group preferred a standard lecture course and two typical responses were: "it makes it easier to understand", and "explains things better and does not waste time writing down everything done in experimentation". The remaining students in the concrete instruction group preferred a course taught concretely because of the involvement and the experience of doing things for themselves.

Four students in the formal instruction group preferred a lecture course because they felt it easier to understand when told what to know. The remaining students in the formal instruction group preferred a laboratory course because they felt it would be less boring, it would be easier to learn by doing experiments and you learn about other people as you learn about the experiments.

The responses made by both groups to item nine were similar. Of particular interest was the number and content of the responses of the formal instruction group in preferring a course based on laboratory experience over a lecture course. The formal instruction group did not experience any laboratory work, yet their reasons for preferring a laboratory course were similar to the responses made by the concrete instruction group.

Item ten asked the students to compare the amount of content material they felt they had learned to other science courses they had taken. Table 6-3 presents the choices available to the students and the responses for both groups to item ten.

TABLE 6-3

RESPONSES TO ITEM TEN OF THE ATTITUDE QUESTIONNAIRE

Response	Concrete Instruction	Formal Instruction
I learned very much less content material than in my other science courses.	0	3
I learned less content material than in my other science courses.	1	3
I learned about the same amount of content material as in my other science courses.	7	5
I learned more content material than in my other science courses.	9	7
I learned very much more content material than in my other science courses.	8	5

Generally, students in both instructional groups felt they had learned more content material than in previous science courses. The concrete instruction group had only one response indicating less or very much less content material was learned than in other science courses and the formal instruction group had six such responses. The concrete instruction group had seventeen responses indicating they learned more or very much more content material than in other science courses while the formal instruction group had twelve such responses.

Item eleven asked the students to compare the amount of content material they felt they had learned to other non-science courses they had taken. Table 6-4 presents the choices available to the students and the responses for both groups to item eleven.

TABLE 6-4

RESPONSES TO ITEM ELEVEN OF THE ATTITUDE QUESTIONNAIRE

Response	Concrete Instruction	Formal Instruction
I learned very much less content material than in my other non-science courses.	3	5
I learned less content material than in my other non-science courses.	4	7
I learned about the same amount of content material than in my other non-science courses.	7	7
I learned more content material than in my other non-science courses.	6	3
I learned very much more content material than in my other non-science courses.	4	1

The concrete instruction group had seven responses indicating less or very much less content material was learned than in other non-science courses while the formal instruction group had twelve such responses. The concrete instruction group had ten responses indicating more or very much more content material was learned than in other non-science courses while the formal instruction group had four such responses.

The responses made for item ten were made by ninth grade students reflecting back to the previous years science courses. The students were also asked to compare their science courses with other ninth grade courses in responding to item eleven.

The questionnaire used to evaluate the students' attitude toward the physical science course was adapted from a questionnaire which had proven highly successful when administered to college freshmen. It was not possible to validate the questionnaire due to the experimental nature of the present study for ninth grade students. This investigator believes, after evaluating the responses made by the students, that the validity of the entire questionnaire is highly questionable. Furthermore the evidence suggested that a concrete operational individual is not able to evaluate himself in terms of what content he has learned, how much content he has learned and how he should best be taught.

CHAPTER VII

SUMMARY, RESULTS, GENERAL CONCLUSIONS AND RECOMMENDATIONS

Summary

The rise of many laboratory-centered science curriculum programs during the last decade raised the question of the effect of the inquiry procedures used by these curricula on the learner. Specifically the learning cycle introduced by the Science Curriculum Improvement Study was evaluated by comparing the inquiry instructional technique to the traditional "show and tell" instructional techniques used in many American Schools. The learning cycle was defined as "Concrete Instruction" and that instructional procedure gave the student actual first hand experience with objects, events and/or situations, for the purpose of allowing the student to find data which would allow the teacher to introduce the concept. When the concept was introduced the learners had an experimental base, or background, that allowed them to understand the meaning of the concepts' label which they had just heard and/or seen. The last phase of the learning cycle permitted learners to discover the usefulness of the concept. The opposing didactic, expository instructional procedure was defined as "Formal Instruction" and consisted of the teacher transmitting to the student directly the information to be learned about the concept. Previous research has shown that concrete operational students are able to learn concepts require concrete operational thinking but are severely limited in their ability to learn concepts that require formal operational thinking.[17]

The purpose of this study was to investigate the relationships between the two instructional procedures and content-achievement, intellectual development and learner I.Q. when concrete operational students were taught concrete operational concepts. This investigation was conducted to find answers to the following questions. What are the relationships between concrete instruction and formal instruction methodologies and the content-achievement and retention of gains made in content-achievement of ninth grade physical science students? What are the relationships between concrete instruction and formal instruction methodologies and the intellectual development and the retention of gains made in intellectual development of ninth grade physical science students? What are the relationships between concrete instruction and formal instruction methodologies and learner I.Q. changes of ninth grade physical science students?

Results

Hypothesis one was tested for significant differences between the means of the content achievement exhibited by the concrete instruction group and the formal instruction group for each content examination. Only on the Static Electricity multiple choice content examination did the formal instruction group exhibit greater gains in content-achievement

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[17]Anton Eric Lawson, "Relationships Between Concrete and Formal Operational Science Subject Matter and the Intellectual Level of the Learner" (unpublished Doctoral dissertation, Unversity of Oklahoma, 1973).

and that difference was significant at the 0.10 level. Two content examinations had differences between the means that were not significant at the 0.20 level; those examinations were Sound, multiple choice and Static Electricity, free response. The remaining content examinations all exhibited difference between the means that were statistically significant at the levels shown below in favor of the concrete instruction group. The level of significance for each difference was: Current Electricity, multiple choice 0.0005, free response 0.005; Light and Optics, multiple choice 0.005, free response 0.05; Sound, free response 0.01; Magnetism, multiple choice 0.05, free response 0.10; Electromagnetism, multiple choice 0.05, free response 0.0005. The combined mean of all examinations for multiple choice exhibited a significant difference at the 0.0005 and free response at the 0.005 level, both in favor of the concrete instruction group.

Hypothesis one was rejected in favor of the concrete instruction group for nine of the twelve content examinations. Hypothesis one was rejected in favor of the formal instruction group for one of the twelve content examinations and accepted for two of the content examinations. Hypothesis one was rejected for the combined means of all of the content examinations in favor of the concrete instruction group.

Hypothesis four was tested for significant differences between the means of the concrete instruction group and the formal instruction group for content post-examinations written approximately three months following the conclusion of each content unit. Due to the hostility of several students in the formal instruction group, the content post-examinations were only given for Static Electricity, Current Electricity, Light and Optics and Sound. Results of t-Ratio tests established that the level of significance for a difference between the means for all four multiple choice examinations was 0.0005 in favor of the concrete instruction group. The Static Electricity and Current Electricity free response examination means were significantly different at the 0.0005 level in favor of the concrete instruction group. The Light and Optics free response means were significantly different at the 0.005 level and the Sound free response means were significantly different at the 0.05 level, both in favor of the concrete instruction group. The combined average means of the four content post-examinations showed significantly different means in favor of the concrete instruction group for both the multiple choice and free response examinations at the 0.0005 level. Hypothesis four was rejected in favor of the concrete instruction group for all of the content post-examinations. The concrete instruction group retained significantly greater content material than the formal instruction group three months following the conclusion of the instruction.

A comparison was made between the group means for the content examinations and the content post-examinatios for each content unit for which data were available: Static Electricity, Current Electricity, Light and Optics, and Sound. The data for Static Electricity showed the concrete instruction group means increased from content examination to content post-examination while the formal instruction group means decreased.

Data for Current Electricity showed both the concrete instruction group means and the formal instrıction group means decreased from content examination to content post-examination. However, the post-examination means of the concrete instruction group were higher than the examination means of the formal instruction group. The data indicated the concrete instruction group retained more content-achievement than the formal instruction group exhibited immediately following the instruction.

Data for Light and Optics showed both the concrete instruction group means and the formal instruction group means decreased from content examination to content post-examination. However, the post-examination means of the concrete instruction group were approximately the same level as the examination means of the formal instruction group. The data indicated the concrete instruction group retained approximately the same level of content-achievement as the formal instruction group exhibited immediately following the instruction.

Data for Sound showed both the concrete instruction group means and the formal instruction group means decreased from content examination to content post-examination. However, the post-examination means of the concrete instruction group were approximately the same as the examination means of the formal instruction group. The data indicated the concrete instruction group retained approximately the same level of content-achievement as the formal instruction group exhibited immediately following the instruction.

Data for the combined average means of the four content post-examination scores showed both the concrete instruction group means and the formal instruction group means decreased from content examination to content post-examination. However, the post-examination means of the concrete instruction group were higher than the examination means of the formal instruction group. The data indicated the concrete instruction group retained approximately the same level of content-achievement as the formal instruction group exhibited immediately following the instruction.

Hypothesis two was tested to determine the effect of instruction method on intellectual development gains made by the students during the experimental procedure. Hypothesis five was tested to determine the effect of instruction method on the retention of gains made in intellectual development three months after the conclusion of the experimental portion of the study. The means of the intellectual development scores as measured by the Piagetian tasks were not significantly different at the 0.20 level at the onset of the study. The conclusion was drawn that the two groups did not initially differ in terms of intellectual development, although the concrete instruction group exhibited a <u>lower</u> mean than the formal instruction group. The means of the intellectual development scores were not significantly different at the conclusion of the experimental portion of the study at the 0.20 level, however, the concrete instruction group now exhibited a <u>higher</u> mean than the formal instruction group. A comparison of mean difference scores in intellectual development of the two groups was statistically different at the 0.10 level. The data for post-posttest of intellectual development showed that both groups made similar gains during the three month interim following the experimental portion of the study. No significant difference in the means of the difference scores was evidenced during this period. The data indicated that students experiencing concrete instruction exhibited significantly greater gains in intellectual development than students experiencing formal instruction. When students from both groups were returned to their regular science classes they exhibited similar gains in intellectual development.

Hypothesis three was tested to determine the effect of instruction method on learner I.Q. during the experimental procedure. Scores were obtained for the Language, Non-language and Overall I.Q. using the Short Form Test of Academic Aptitude,[18] Level 5. At the onset of the study data from the I.Q. pretest showed that no significant difference existed between the concrete instruction group and the formal instruction group on any of the three I.Q. scores. At the conclusion of the experimental portion of the study the students were given the same instrument as a posttest. The data did not show any significant differences in I.Q. between the means of the two instruction groups. Mean difference scores were then calculated and tested for significance using the t-Ratio test. No significant differences were found in the mean difference scores for the Language and the Overall I.Q.s, however, a difference was found in the mean difference scores for the Non-language portion in favor of the concrete instruction group at the 0.10 level of significance.

An attitude questionnaire was administered to each student on the last day of the experimental portion of the study. The students were asked to evaluate their feelings about the course. The responses of

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[18]Elizabeth T. Sullivan, Willis W. Clark and Ernest W. Teigs, Short Form Test of Academic Aptitude, Level 5 (Monterey, California: CTB/McGraw-Hill, 1970).

the students indicated that ninth grade students, who were primarily concrete operational, were not able to evaluate the instruction method they have experienced. This investigator believes that such evaluations could not be made by concrete operational thinkers using the attitude questionnaire utilized in this study.

General Conclusions

The conclusions drawn by this study indicate that a change from the traditional, didactic "Formal Instruction" method of teaching to the inquiry, "Concrete Instruction" method of teaching is certainly justified for the concrete operational science student. Indeed such a change is imperative for the teacher and/or administrator concerned with the quality of science education the students receive. The striking gains in content-achievement and the retention of these gains made by the group experiencing concrete instruction over the group experencing formal instruction strongly indicate that actual first hand experience with objects, situations and/or events builds the mental structures necessary to function with a science concept.

The greater gains made in intellectual development by the concrete instruction group over the formal instruction group during the experimental procedure indicate that the concrete instruction technique is superior to the formal instruction technique in promoting intellectual development for the concrete operational student. The implication for educators concerned with promoting intellectual development in students is that the actual first hand experience of concrete instruction should replace formal instruction techniques where they are currently being used.

Recommendations

Further research needs to be done to extend the findings of this study to other science concepts. Additional research is needed to determine whether the findings of this study are applicable to students outside the socio-economic class, demographic range, intellectual development range and I.Q. range as the students who participated in this study.

The probability of committing Type II error in this investigation was controlled by the size of the sample. An increase in the sample size would result in a decrease in the probability of committing such error. Due to the strong educational implications evidenced by this research, additional investigations need to be conducted utilizing larger samples.

In this study the same concepts were used with both instruction groups. The formal instruction group, however, experienced the usual formal language associated with such concepts as electrical current. Did the use of the formal language make an otherwise concrete concept a formal concept? Were the results of this study obtained because of the previously known fact that concrete learners cannot learn formal concepts? Is teaching a concrete concept formally possible, or do all concrete concepts become formal when taught formally? If the latter question is answered affirmatively it has profound implications for anyone teaching concrete operational thinkers; any type of exposition on any topic is ruled out because the concept being talked about has immediately become formal. Such topics need research.

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APPENDIX A

CONTENT EXAMINATIONS

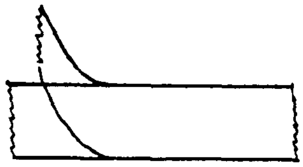
AND

SAMPLE RESPONSES

PHYSICAL SCIENCE * * * STATIC ELECTRICITY * * * NAME__________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER * * * MULTIPLE CHOICE

Circle the letter of the word or phrase which best answers the following questions. Then write a paragraph explaining why you chose your answer.

1. Two pieces of tape can be charged with opposite charges by first sticking the front of one to the back of the other, then pulling them apart rapidly. (See diagram.) Disregarding the effect of the glue, how will one of these pieces behave in the following situation?



(a) It will repel the second piece of tape and attract a third neutral piece of tape.
(b) It will attract the second piece of tape and attract a third neutral piece of tape.
(c) It will repel the second piece of tape and repel a third neutral piece of tape.
(d) It will attract the second piece of tape and repel a third neutral piece of tape.

2. Which of the following statements explains why the leaves of a charged electroscope spread?

(a) They are attracted to the sides of the electroscope.
(b) The electroscope is grounded.
(c) The like charges on each leaf repel.
(d) Electricity influences gravity inside the electroscope.

3. Which of the following evidence indicates that static electricity is a form of energy?

(a) Pieces of nylon cloth will stick together.
(b) The leaves of an electroscope will stand apart.
(c) Neither (a) or (b).
(d) Both (a) and (b).

4. Which of the following types of materials would make good insulating materials?

(a) Materials that will allow electric charge to move along them easily.
(b) Materials that are able to become easily charged although they are grounded.
(c) Neither (a) or (b).
(d) Both (a) and (b).

5. Which of the following statements explains how a charged electroscope is discharged by grounding it with your finger?

(a) Your body is a good conductor and will dissipate the electricity to the air easier than the electroscope knob.
(b) Your body acts as a large source of electricity and allows the small amount on the electroscope to move in and out easily.
(c) The electroscope is sensitive to the minute amounts of pressure provided by your body.
(d) The electroscope will respond to minute temperature changes provided by your body.

6. Which of the following statements explains why you are unable to ground a positively charged electroscope with a glass rod?

(a) A glass rod will not hold a positive charge.
(b) A glass rod will not hold a negative charge.
(c) A glass rod will not allow a positive charge to move on it.
(d) A glass rod will not attract the knob of a positively charged electroscope.

7. A glass rod can be given a charge by rubbing it with silk cloth. Which of the following statements best describes the glass rod and the silk?

(a) The electric charge on the glass rod comes from the ground rather than the silk.
(b) The glass rod is charged but the silk does not acquire an electric charge.
(c) The glass rod and the silk both acquire the same electric charge.
(d) The silk acquires the opposite electric charge as the glass rod.

8. A charged object will attract small pieces of paper. However, if you wipe the object with your bare hand, it will no longer attract the pieces of paper. Which of the following statements best explains this apparent loss of electric charge?

(a) Your hand spreads out the charge over the entire rod thus weakening its affect.
(b) Rubbing your hand over the rod gives it the opposite charge as it originally possessed.
(c) You hand has no noticible affect on the charge on the rod.
(d) Your hand neutralizes the charge on the rod by grounding it.

9. You bring an object near the knob of a charged electroscope and the leaves of the electroscope are spread even farther. Which of the following statements best describes what would happen to the leaves of the electroscope if you were then to touch the knob with the object?

(a) The leaves of the electroscope would return to their original position.
(b) The leaves of the electroscope would collapse.
(c) The leaves of the electroscope would remain spread at the farthest position.
(d) Not enough information is known about the object to predict what the leaves of the electroscope would do.

10. Light materials will be attracted to a charged object whether or not they are charged. Which of the following tests will allow you to determine whether or not these light materials have an electric charge?

(a) Continue testing using the same charged object to determine its reaction with the materials.
(b) Test the reaction of the materials to another object with the same charge as the first object.
(c) Test the reaction of the materials to another object with the opposite charge as the first object.
(d) Use other similar materials to test for a reaction between them and the original charged rod.

PHYSICAL SCIENCE * * * STATIC ELECTRICITY * * * NAME_____________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER * * * FREE RESPONSE

Answer the following questions in complete sentences. Be as complete in your answers as possible.

1. When you rub a balloon with a piece of silk material it will become charged. It is then possible to stick the balloon to a wall without using any other means of support. Explain how this is proof that static electricity is a form of energy.

2. What is the difference between materials that are good conductors and materials that are good insulators?

Give as many examples as you can of materials that are good conductors.

Give as many examples as you can of materials that are good insulators.

3. An electroscope is an instrument that will detect an electric charge. The leaves of an electroscope will behave the same in the presence of both a positive and a negative charge. Explain what causes the leaves of the electroscope to spread.

4. An electroscope is charged with a positive charge using a glass rod. Explain what will happen to the leaves of the electroscope in each of the following situations.

(a) A second charged positive glass rod is brought <u>near</u> the knob.

(b) A charged negative rubber rod is brought <u>near</u> the knob.

(c) A neutral glass rod is brought <u>near</u> the knob.

(d) A neutral rubber rod is <u>touched</u> to the knob.

(e) A charged positive glass rod is <u>touched</u> to the knob and then <u>removed</u> from the electroscope.

5. One way to discharge an electroscope is to touch it with your finger. Scientists sometimes call discharging an electroscope 'grounding'. Explain what will happen in the following situations.

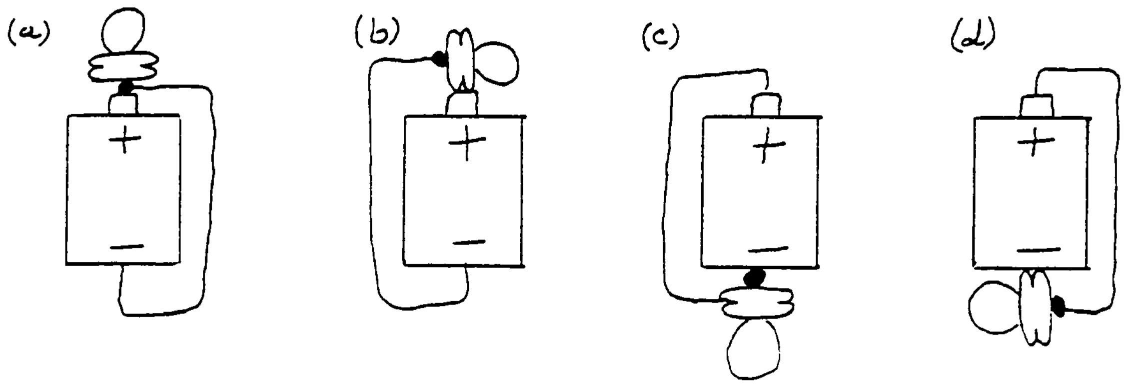
(a) You touch the knob of a charged electroscope with a table knife while holding the other end in your hand.

(b) You touch the knob of a charged electroscope with a piece of paper while holding the other end of the paper in your hand.

PHYSICAL SCIENCE * * * CURRENT ELECTRICITY * * * NAME___________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER * * * MULTIPLE CHOICE

Circle the letter of the word or phrase which best answers the following questions. Then write an explanation using complete sentences telling why you chose your answer.

1. From the drawings below select the one that will <u>not</u> allow an electric current to light the bulb.



2. In which of the following ways is a dry cell different from a wet cell?

(a) The number of electrodes or poles.
(b) The path of the flow of electricity.
(c) The electric current that is produced.
(d) The materials used in construction.

3. Adding dry cells in series to a circuit changes the circuit. Which of the following statements explains how the circuit is changed?

(a) The resistance of the circuit increases.
(b) The voltage in the circuit decreases.
(c) More current flows in the circuit.
(d) There is less resistance in the circuit.

4. Adding more resistances in series to a circuit will change the circuit. Which of the following statements explains how the circuit is changed?

(a) The voltage of the circuit increases.
(b) Less current flows in the circuit.
(c) The voltage of the circuit decreases.
(d) There is no change in the amount of current in the circuit.

5. Which of the following statements explains why there must be two connections to a dry cell to produce an electrical current?

(a) Two wires provide more electricity than one and that much is required.
(b) Electricity moves along a path from one pole of a dry cell to the other pole.
(c) Neither (a) or (b).
(d) Both (a) and (b).

6. Which of the following statements explains how adding more dry cells in parallel to a circuit affects the circuit?

(a) The total current in the circuit increases.
(b) The total current mains unaffected in the circuit.
(c) The total current in the circuit decreases.
(d) There is not enough information given to determine the affect on the current.

7. Which of the following statements explains how adding more resistances in parallel to a circuit affects the circuit?

(a) The resistances will allow more total current in the circuit.
(b) The resistances will not cause any change in the total current in the circuit.
(c) The resistances will cause less total current in the circuit.
(d) There is not enough information given to determine the affect of the resistances on the current.

8. Which of the following statements explains how a switch must be placed in a series circuit to be functionally operative.

(a) The placement of the switch in the circuit makes no difference.
(b) The switch will operate at some positions but not at other positions.
(c) The switch must be placed as close to the power source as possible.
(d) The switch must be placed as close to one of the resistances as possible.

9. Which of the following best describes what a switch does in a circuit?

(a) A switch decreases the total amount of current in the circuit.
(b) A switch stops the flow of current in a circuit.
(c) A switch decreases the resistance of a circuit.
(d) A switch increases the flow of current in a circuit.

10. Which of the following statements explains what happens when a wet cell 'runs down'?

(a) The anode appears to dissolve in the solution.
(b) The cathode appears to dissolve in the solution.
(c) Both the anode and the cathode appear to dissolve in the solution.
(d) The solution gives up all the electricity it contained.

PHYSICAL SCIENCE * * * CURRENT ELECTRICITY * * * NAME__________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER * * * FREE RESPONSE

Answer the following using complete sentences. Be as complete in your answer as possible.

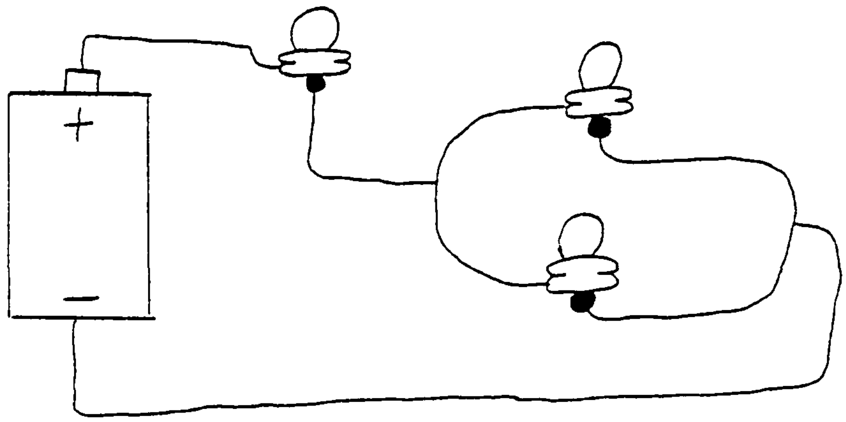
1. What is the function of a switch in an electrical circuit? Include in your discussion how a switch performs its function and how it may be connected in a circuit.

2. Below is a drawing of an electrical circuit.

(a) If possible put an 'A' in the circuit at a position where a switch would control all three lamps in the circuit. If this is not possible explain why.

(b) If possible put a 'B' in the circuit at a position that would control lamp #2 only. If this is not possible explain why.

(c) If possible put a 'C' in the circuit at a position that would control lamps #1 and #3 only. If this is not possible explain why.



Explanations (if necessary):

3. Explain what happens to the total current of a series circuit as additional resistance is added to the circuit while the voltage is kept constant.

4. Explain what happens to the amount of current supplied by <u>each</u> dry cell as additional dry cells are added in parallel to a circuit while the resistance is kept constant.

5. Explain why two contacts to a dry cell are required to provide electrical current in a circuit.

6. (a) Explain how a wet cell is different from a dry cell.

(b) Explain how a wet cell is similar to a dry cell.

7. Explain what happens when an electrical cell 'runs down'.

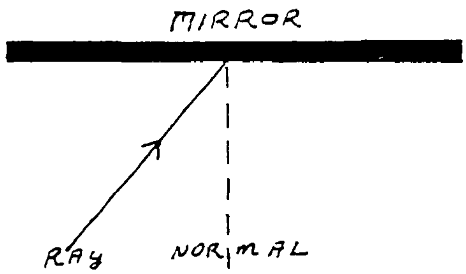
PHYSICAL SCIENCE * * * LIGHT & OPTICS * * * NAME____________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER * * * MULTIPLE CHOICE

Circle the letter of the phrase that best answers each of the following questions. Then write a paragraph explaining why you chose your answer.

1. Which of the following statements gives evidence that light travels in straight lines?

(a) The path of the sun across the sky each day is a straight line.
(b) The ancient Greeks thought light rays originated in the eye.
(c) A simple pinhole camera will allow light to form an image on the film.
(d) It is possible to see on a cloudy day when the sun is not visible.

2. The following diagram shows a mirror and a ray of light striking the mirror.



Which of the following statements best describes what happens to the ray of light?

(a) The ray is reflected on the opposite side of the normal at the same angle as it entered the mirror.
(b) The ray is reflected on the same side of the normal along the same path as it entered the mirror.
(c) The ray is absorbed by the mirror at the normal and reflected from another point on the mirror.
(d) Part of the ray continues through the mirror to form a reflection behind the mirror.

3. The image of an object produced by a plane mirror is called a virtual image because the light rays do not pass through the apparent position of the image. Which of the following statements does <u>not</u> describe the image produced by a plane mirror?

(a) The image appears to be reversed from right to left.
(b) The image appears to be as far behind the mirror as the object is in front of the mirror.
(c) The image appears to be the same size as the object.
(d) The image appears to be inverted from top to bottom.

4. Refraction is the bending of light as it passes from one transparent medium to another. Which of the following statements describe the refraction of light as it goes from air to water?

(a) The angle of refraction increases as the angle of incidence increases.
(b) The angle of refraction is always larger than the angle of incidence.
(c) Total internal reflection from air to water is possible when the angle of incidence is large.
(d) The light rays are bent away from the normal.

5. A convex lens uses the property of refraction to control light. Which of the following statements best describes the focal length of the lens?

(a) The focal length on the side of the lens toward the object is longer than the focal length of the side toward the image.
(b) The focal length of the side of the lens toward the image is longer than the focal length of the side toward the object.
(c) The focal length of the lens is always the same on both sides of the lens.
(d) There is not enough information given to determine the relative lengths of the two focal length of the lens.

6. A convex lens produces a real image because the light rays of the object actually pass through the image. Which of the following statements best describe the image produced when the object is outside the focal length?

(a) The real image is always smaller than the object.
(b) The real image is always larger than the object.
(c) The real image is always right side up.
(d) The real image is always inverted.

7. A convex lens will produce a virtual image when the object is inside the focal length. Which of the following statements best describes the image produced?

(a) The virtual image is larger than the object and right side up.
(b) The virtual image is larger than the object and inverted.
(c) The virtual image is smaller than the object and right side up.
(d) The virtual image is smaller than the object and inverted.

8. White light is composed of three primary colors: red, green, and blue. Which of the following statements best describes how black is formed?

(a) Black is formed by the addition of red, blue and green.
(b) Black is formed by the subtraction of red, blue and green.
(c) Black is formed by the addition of red, blue and yellow.
(d) Black is formed by the subtraction of red, blue and yellow.

9. An object appears green when viewed under white light. Which of the following statements describes the color the object will appear under blue light?

(a) Blue light will cause the object to appear blue.
(b) The object will appear black when viewed under blue light.
(c) Blue light will cause the object to appear green.
(d) The object will appear yellow when viewed under blue light.

10. Modern color television is produced by three electric circuits. Each circuit produces a different color: red, green and blue. Suppose that the circuit that produces blue on the screen fails, but the rest of the television receiver operates normally. Which of the following statements describes how a black and white picture broadcast from the television station would appear on such a television receiver?

(a) The picture would appear black and red.
(b) The picture would appear black and green.
(c) The picture would appear black and yellow.
(d) The picture would appear black and blue.

PHYSICAL SCIENCE * * * LIGHT & OPTICS * * * NAME____________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER * * * FREE RESPONSE

1. (a) Suppose you look at an object such as a pencil. You see it because light travels in a straight line from the pencil to your eyes. You see it there in front of your. You reach out and can touch it. This evidence shows that light travels in straight lines. If the light did not travel in straight lines you would not be able to touch the pencil. Things would not acutally be where you see them with your eyes. Write a paragraph giving your reaction to this statement.

(b) Now consider another piece of evidence. A simple pinhole camera will allow light to form an image on the film. If light did not travel in straight lines it would be impossible to form an image on the film. This is proof that light travels in straight lines. Write a paragraph giving your reaction to this evidence.

(c) Now start with an assumption that light travels in straight lines. Use this assumption in all your explanations and predictions about light. So long as your assumption does not lead to contradiction it must be right. Write a paragraph giving your reaction to this statement.

2. The ancient Greeks thought the reason you can see an object is because your eyes emit light rays which strike an object and then bounce back to your eyes. They thought you see a red object because your eyes send out red light to that object. Similarly they thought you see a green object because your eyes send out green light to the object. Furthermore, they thought you could not see after the sun went down because it was night.

Explain how the model of vision used today is different from the model of vision the ancient Greeks used.

3. (a) Describe the position and size of the real image produced by a lens when the object is very far away from the lens.

(b) Describe the position and size of the real image produced by a lens when the object is very near but outside the focal point of the lens.

(c) Describe the virtual image produced by a lens when the object is inside the focal length of the lens.

4. Explain what gives an object its color. In other words, explain why a red object appears red, a blue object appears blue, etc.

5. (a) What color would a green object appear under white light?

(b) What color would a green object appear under green light?

(c) What color would a green object appear under blue light?

(d) What color would a green object appear under red light?

(e) What color would a green object appear under yellow light?

6. A color television uses three circuits to produce a red picture, a blue picture and a green picture. All three pictures overlap each other at the same place on the screen. Explain how a black and white picture is produced on a color television set. Does a color television operate using the addition model or the subtraction model of color?

7. White is sometimes defined as the presence of all color. Black is sometimes defined as the abscense of all color. Explain how black may be produced. Include in your discussion which colors are needed to produce black and which model of color allows you to produce black.

PHYSICAL SCIENCE * * * SOUND * * * NAME________________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER * * * MULTIPLE CHOICE

Circle the letter of the phrase that best answers the following questions. Then write a paragraph explaining why you chose your answer.

1. Musical instruments produce sound by causing the air to vibrate. Which of the following statements explain how a low pitch is produced?

(a) A low pitch is produced by a vibration of small amplitude.
(b) A vibration of low frequency will produce a low pitch.
(c) A low pitch is produced by a vibration of large amplitude.
(d) A vibration of high frequency will produce a low pitch.

2. Sound travels from one place to another through a medium. Which of the following statements best related to sound in a vacuum?

(a) Sound will travel through a vacuum as well as through air.
(b) Sound will travel through a vacuum better than through air.
(c) Sound will not travel through a vacuum as well as through air.
(d) A vacuum will not allow any sound to travel through it.

3. An echo is the reflection of sound from a distant surface. Which of the following statements describes the path of sound in an echo when the sound strikes the surface at an angle?

(a) The sound will bounce straight off the smooth surface.
(b) The surface will reflect the sound at the same angle as it strikes the surface.
(c) The sound will be reflected back along its original path.
(d) The surface will magnify the sound as it is reflected.

4. Eachoes are not wanted in music halls and other large rooms. To avoid those echoes, large, heavy drapes are often hung. Which of the following statements explains how the drapes will help avoid echoes?

(a) The irregular surface of the drapes scatters the sound in many directions.
(b) The soft material of the drapes absorbs the sound.
(c) Neither (a) or (b).
(d) Both (a) and (b).

5. A piano produces low pitches using long wires and high pitches using short wires. Which of the following statements best describes the vocal cords of men's low voices and women's high voices?

(a) The vocal cords of men are usually longer than those of women.
(b) The vocal cords of men are usually shorter than those of women.
(c) The vocal cords of men and women are usually the same size.
(d) Not enough information is given to determine the size of the vocal cords.

6. As you grow older you will lose the ability to hear very high pitches that you now can hear. Which of the following statements best describes those pitches when you are no longer able to hear them?

(a) The pitches you are no longer able to hear will no longer be called sound.
(b) The pitches will still be called sound even though you are no longer able to hear them.
(c) The vibration of the pitches ceases to exist when you are no longer able to hear them.
(d) The instrument producing the pitches ceases to vibrate at those frequencies when you are not able to hear them.

7. It is possible to distinguish the sounds produced by a trumpet and a violin by their sound alone. Which of the following statements describes how this distinction is made.

(a) A violin and a trumpet cannot produce the same pitch.
(b) A violin and a trumpet produce sounds of different loudness.
(c) A violin and a trumpet have a different timbre.
(d) A trumpet does not produce vibrations but a violin does.

PHYSICAL SCIENCE * * * SOUND * * * NAME________________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER * * * FREE RESPONSE

Answer the following using complete sentences. Be as complete in your answer as possible.

1. Explain the property of sound that enables a trumpet to produce first a high note and then a low note. Be sure to name this property in your explanation.

2. Explain the property of sound that enables you to distinguish between a piano and a trumpet. Be sure to name this property in your explanation.

3. Explain the property of sound that enables a piano to produce first a loud sound and then a soft sound. Be sure to name this property in your explanation.

4. Three essential factors are required in order for sound to exist. Name these factors.

   1.
   2.
   3.

Use your answer to number four to answer numbers five, six and seven.

5. Explain why sound would not exist if the first property was absent but the second and third properties were present.

6. Explain why sound would not exist if the second property was absent but the first and third properties were present.

7. Explain why sound would not exist if the third property was absent but the first and second properties were present.

PHYSICAL SCIENCE * * * MAGNETISM * * * NAME____________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER * * * MULTIPLE CHOICE

Circle the letter of the phrase which best answers the following questions. Then write a paragraph explaining why you chose your answer.

1. Which of the following best describes the position of magnetic poles in a magnet?

(a) The poles are always at the same end of the magnet.
(b) The poles are always at opposite ends of the magnet.
(c) The poles are sometimes at the same end and sometimes at opposite ends of the magnet.
(d) The poles are always moving and sometimes difficult to locate.

2. When two magnets are brought near each other they will interact. In which of the following situations will the magnets be most likely to repel?

(a) (b) (c) (d)

3. Magnetic poles are an important property of a magnet. Which of the following is characteristic of magnetic poles?

(a) The magnetic poles are the only places on a magnet that will attract small pieces of paper.
(b) Magnetic poles can be detected on a glass rod under certain conditions.
(c) The attraction of unmagnetized iron is concentrated at the magnetic poles.
(d) Magnetic poles are the only places on a magnet that will attract unmagnetized iron.

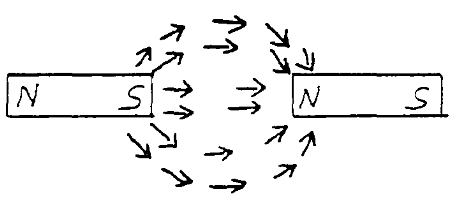
PHYSICAL SCIENCE * * * MAGNETISM * * * PAGE TWO

4. A compass is a permanent magnet that is free to rotate on a pivot at its center. Which of the following best describes why a compass is a good tool with which to determine direction?

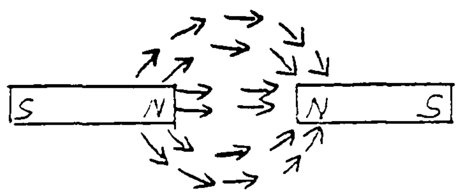
(a) The rotation of the earth forces the compass to align itself along the North-South direction.
(b) The sun gives off radiation which affects the position of a compass.
(c) A compass always points up which is toward the North pole at the top of the earth.
(d) The earth acts as a giant magnet with which the compass aligns itself.

5. A compass was used to map the magnetic field of two magnets. The arrows indicate the North direction of the campass needle. Which of the following best describes the magnetic field.

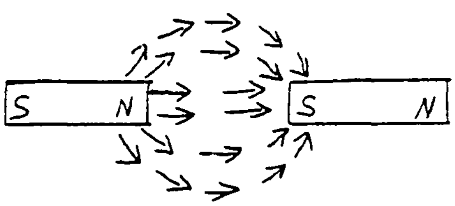
(a)



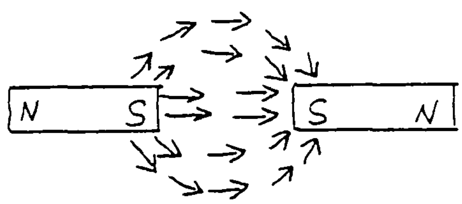
(b)



(c)



(d)



6. A permanent magnet is cut in two pieces half way between the poles. Which of the following best describes the piece that originally contained the North pole?

(a) A new magnet is formed containing only a North pole.
(b) A magnet with a strong North pole and a weak South pole results.
(c) Equal strength North and South poles are in the new magnet.
(d) The material loses its magnetic properties.

PHYSICAL SCIENCE * * * MAGNETISM * * * NAME_______________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER * * * FREE RESPONSE

Answer the following questions using complete sentences. Be as complete in your answer as possible.

1. (a) How do unlike magnetic poles behave when they are near each other?

   (b) How do like magnetic poles behave when they are near each other?

2. What effect does distance have on the forces between magnetic poles?

3. How can you detect the magnetic field that surrounds a magnet?

4. What is the shape of the magnetic field surrounding a bar magnet?

5. How large is the magnetic field around a bar magnet in relation to the size of the magnet?

6. (a) What kinds of materials do magnets attract?

   (b) What kinds of materials do magnets not attract?

7. How does a magnetic compass give you direction?

8. If you were lost in Philadelphia and wanted to travel in a direction true west, how would you locate true west with nothing to aid you but a magnetic compass? Would you use the same procedure in Phoeniz? If not what procedure would you use in Phoenix?

PHYSICAL SCIENCE * * * ELECTROMAGNETISM * * * NAME____________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER * * * MULTIPLE CHOICE

Circle the letter of the word or phrase that best answers the following questions. Then write a paragraph indicating why you chose your answer.

1. A current flowing through a straight section of wire produces a magnetic field around the wire. Which of the following statements explains how increasing the current in the wire affects the field?

(a) The shape of the magnetic field becomes more circular.
(b) The magnetic poles become more pronounced.
(c) The length of the magnetic field becomes shorter.
(d) None of the above.

2. A current flowing through a circular loop of wire produces a magnetic field. Which of the following statements best describes the field?

(a) The direction of the magnetic field in the center of the loop depends on the direction the current is flowing.
(b) A compass placed in the center of the loop will spin rapidly.
(c) The magnetic field is weaker at the center of the loop than outside the loop.
(d) The magnetic field which is found at the center of the loop will <u>not</u> attract iron filings.

3. A very useful property of electromagnets is that they can be made extremely powerful. Which of the following changes in an electromagnet would <u>not</u> increase its strength?

(a) The addition of more coils of wire wound in the same direction as the original coils.
(b) An increase in the amount of current flowing through the coils.
(c) The addition of an automatic rapid switching device to reverse the current as required.
(d) The placement of an iron core through the center of the coils.

4. An electromagnet resembels a bar magnet in many respects. Which of the following statements best indicates a difference between a bar magnet and an electromagnet.

(a) There is a presence of two poles.
(b) A magnetic field surrounds the magnet.
(c) The magnet will attract pieces of iron.
(d) The direction of magnetism can easily be reversed.

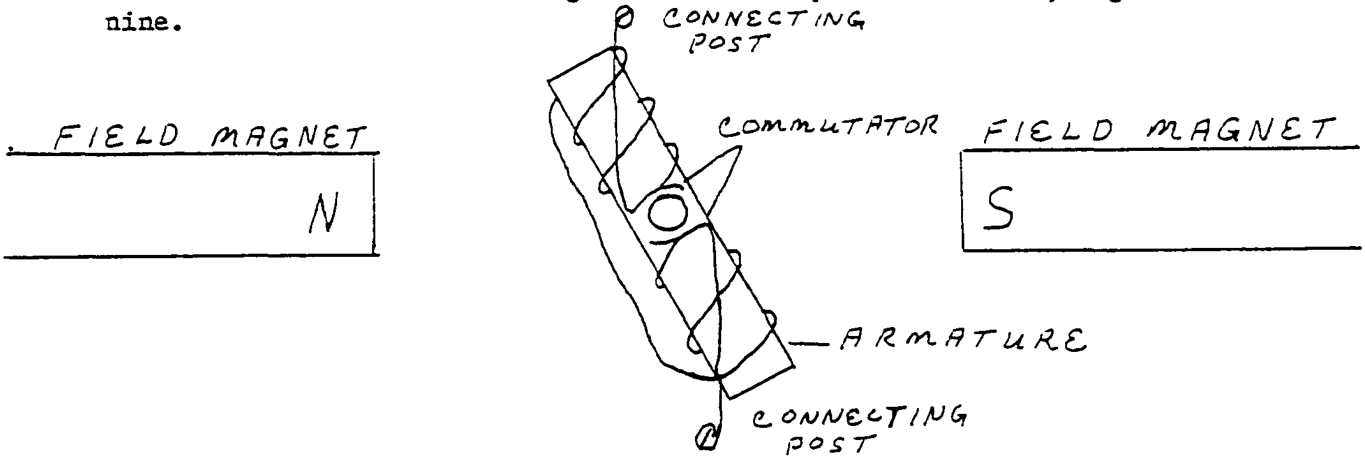
5. An electric motor is a machine that converts electromagnetic energy to mechanical energy. Which of the following examples also convert electromagnetic energy to mechanical energy?

(a) A telegraph system sending a coded message.
(b) An electric ammeter indicating a current.
(c) Neither (a) or (b).
(d) Both (a) and (b)

6. It is possible to produce an electric current in a closed circuit by moving a wire through a magnetic field. Which of the following statements best explains how the current is produced.

(a) The current will be produced as long as the wire remains in the magnetic field.
(b) The current always flows in one direction in the circuit.
(c) The amount of current depends on the speed of the wire moving in the magnetic field.
(d) The amount of current depends on the direction of the movement of wire in the magnetic field.

The diagram below shows two field magnets, a simple armature and a commutator. Refer to the diagram to answer questions seven, eight and nine.



7. Which of the following statements best applies to the diagram when one of the field magnets is removed and the armature is connected to a source of direct current?

(a) The armature will not move from its present position.
(b) The armature will swing less than one-half turn (180°) to align itself in the magnetic field.
(c) The armature will rotate but at reduced speed and power.
(d) The armature will rotate at full speed and power.

8. Which of the following statements best applies to the diagram when one of the field magnets is reversed and the armature is connected to a source of direct current?

(a) The armature will not move from its present position.
(b) The armature will swing less than one-half turn (180°) to align itself in the magnetic field.
(c) The armature will rotate but at reduced speed and power.
(d) The armature will rotate at full speed and power.

9. It is possible to use the apparatus in the diagram to generate electric current. Which of the following explains what happens to the flow of electricity in the <u>coils</u> of the armature when it is rotated in the magnetic field?

(a) There is no change in the direction of the current in the coils as the armature rotates.
(b) The current reverses direction with each complete revolution (360°) of the armature.
(c) The current reverses direction with each half revolution (180°) of the armature.
(d) The current reverses direction with each quarter revolution (90°) of the armature.

PHYSICAL SCIENCE * * * ELECTROMAGNETISM * * * NAME______________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER * * * FREE RESPONSE

Answer the following questions using complete sentences. Be as complete in your answer as possible.

1. What is the shape of the magnetic field that is produced by a straight section of current carrying wire?

2. What does winding a wire into a coil do to the shape of the magnetic field around the wire?

3. What are three things that can be done to a coil of wire to increase its electromagnetic strength?

  1.

  2.

  3.

4. What is the purpose of the armature in an electric motor?

5. What is the purpose of the field magnets in an electric motor?

6. What is the purpose of the commutator in an electric motor?

7. What must be done to an electric motor to convert it to a generator of electric current?

8. Explain how a simple telegraph operates.

9. Explain how a buzzer converts electromagnetic energy to sound energy.

SAMPLE RESPONSES * * * LIGHT & OPTICS - MULTIPLE CHOICE

ITEM ONE:
CORRECT RESPONSES

(C) If light did not travel in straight lines, then nothing would be on the film.

(C) When we did the experiment with the camera, rays of light would escape inside.

(C) Because it is true, and even though the little pinhole is very little, the sunlight can still manage to enter the pinhole.

(C) Because if light didn't travel in a straight line, you would not be able to get an image because it takes light for the picture to focus and produce it.

(C) If light didn't travel in straight lines, then on a camera you would have a different picture than what you aimed for.

INCORRECT RESPONSES

(A) Because if the sunlight did not travel in a straight line, then everything would be blurry.

(D) Because on a cloudy day, you could tell that the sun shines in a straight line when the clouds move.

(D) Because the rays of light are visible on a cloudy day.

(B) The light had to go straight from the eye so they could look straight at things.

(A) The rays of the sun shine in a straight line.

ITEM TWO:
CORRECT RESPONSES

(A) The ray bounces off the smooth surface and travels back at a different angle than it entered.

(A) Because the ray of light reflected on the opposite side of the normal is where the rays of light are. They go in the middle of the mirror.

(A) The mirror is shiny, and the light will bounce off at the same angle opposite the normal like a ball bounces off something.

(A) The ray is going up to the mirror, and the mirror makes this reflect on the opposite side at the same angle as it entered.

(A) It reflects at the same angle it went into the mirror at.

INCORRECT RESPONSES

(C) This is caused by reflection. The light cannot go through a mirror, so this is then reflected to another responding part and thus causes it to absorb.

(D) The ray passes through it so you can see yourself.

(B) Because when a light ray is reflected, it will not go in a straight line. It is bent line.

(B) Because light goes straight.

(B) The normal one is in the center, and the ray hits the same point but reflects a different angle.

ITEM THREE:
CORRECT RESPONSES

(D) A mirror doesn't show anything upside down, just backwards. You would have to stand on your head to see yourself right.

(D) It is not inverted from top to bottom.

(D) The object is still right side up when it comes out of the mirror.

(D) That is only if you look into a convex mirror.

(D) The image is the same but backwards on the appearance.

INCORRECT RESPONSES

(B) Because there is nothing in the mirror. It is just a reflection.

(A) Because it refracts the light, bends it so it comes out in a different place.

(B) Because the mirror blocks the sunlight from going behind theirror, and it will not reflect on behind it.

(C) If you have a mirror, and you wanted to sit in the grass and look backwards and see your house, you would look back and see that the mirror makes the house smaller than it is.

(B) Because you can tell by looking into a plain mirror.

ITEM FOUR:
CORRECT RESPONSES

(A) The more the angle, the more the light will bend.

(A) The bigger the angle of incidence ray, the bigger the angle it will even go out the side instead of back if it's big enough.

(A) The light is bent and comes out larger on the glass of the fish tanks.

(A) When the light shines through the glass, it bounced off the side of it and reflected the same way.

(A) The larger the incidence, the larger the refraction.

INCORRECT RESPONSES

(B) When you put a pencil in the water, it makes it look bigger.

(D) It has to bend away so it will work right, and it bends when the light rays hit the normal.

(D) Because when light hits the water, it angles. For instance, if you were shooting a fish, you have to aim lower.

(A) Because when it hits the water, it goes all through the water.

ITEM FIVE:
CORRECT RESPONSES

(C) The focal length is the same on both sides of the lens, so it can control light the same way on both sides of the lens.

(C) They are always the same length on both sides of the mirror.

(C) The lens is the same thickness on the side and in the middle on both sides, and the thickness enables it to focus with the edges.

(C) Because the image is the same focal length on both sides and is also the same size.

(C) No matter how you turned it, it would be the same on both sides.

INCORRECT RESPONSES

(A) When it might be one centimeter away from the focal length, it usually is closer to the opposite one.

(D) The relative length of the two focal of the lens because there are two lenses, both the same size.

(B) Because the light goes through the lens, and the focal length is the length it takes to focus.

(B) Because the light passes through the lens, and the focal length is the length at which it is focused.

(A) You have to get a lot of distance from the sun to the object to burn something.

ITEM SIX:
CORRECT RESPONSES

(D) The lens makes the object look upside down when you look at the image.

(D) If you get close enough to an object, you can get it the same size, but it will always be inverted.

(D) Like in a camera, the image is always inverted.

(D) When we were working with the lens, the object which we looked at was upside down.

(D) The object will always be inverted because it is backwards.

INCORRECT RESPONSES

(B) The image gets larger when the focal length is far away from the object.

(A) Because when you see it through there, it is smaller than if you see it without the lens.

(B) It becomes real large when you move the lens away from the object.

(B) Bcause the convex lens are thicker in the middle and thinner around the edges.

ITEM SEVEN:
CORRECT RESPONSES

(A) The convex lens causes the image to just appear this way even though it is right side up.

(A) Because it magnifies it, and it's in the focal length, so it's right side up.

(A) It blows up the size but stays right side up.

(A) When the lens is in focal length, the image appears magnified and right side up because you are supposed to use it to make small things large.

(A) Because it produces a virtual image of the object inside the focal length.

INCORRECT RESPONSES

(A) When you look in a mirror, you aren't behind it.

(D) The virtual image is smaller because the light is refracted, so it makes the object smaller, also upside down.

(C) The object is small but is right side up with the focal length is very close to the object.

(D) A virtual image is like shining the flashlight through the lens, and the bulb appeared to be there.

(B) Because when the focal length is inside the focal length of the object, it would make it bigger.

ITEM EIGHT
CORRECT RESPONSES

(D) After you subtract red, bule, and yellow, there is nothing left but black.

(D) Black is absence of all color since red, blue, and yellow are the base colors. Then when you subtract them, you have black because red, blue, and yellow don't have any color in common.

(D) Black is subtracted by all of the colors.

(D) This is true because as you take away all other colors, there is only one color left, which is black.

(D) You can combine these colors by subtraction and get the color black. These three colors are primary colors for artists.

INCORRECT RESPONSES

(B) Black is formed when you put all three colors together, and they make black.

(C) When you add red, blue and yellow, you get black.

(A) Scientist's colors are added; artist's colors are subtracted.

(B) You add all of them colors together, and they just fade into black because they are too dark.

(B) You add red and blue together you get violet, but when you add green you get black.

ITEM NINE:
CORRECT RESPONSES

(B) Because blue has no mixture of green; therfore, it reflects nothing.

(B) Because green looks black with a blue light.

(B) Because the color blue absorbs every color but blue.

(B) When you have a green object under a blue light, it turns black.

(B) When you use the subtraction method, you get black.

INCORRECT RESPONSES

(D) Green and blue make the object appear yellow.

(D) The object was green, and then on top of it was blue, so it will turn yellor.

(B) Because it would look green under dark light.

(A) Viewed under blue light, the blue took out the colors but blue.

(B) Blue is a dark color. The object will become darker.

ITEM TEN
CORRECT RESPONSES

(C) Because the absence of the blue means that the red and green would mix, and it would become black and yellow.

(C) Because blue and yellow makes green. When the blue goes out, the color yellow shows through as well as black. Note: Evidence of understanding, reason not precise -- five points for correct selection.

(C) By adding the two colors together, that's what you would get.

(C) Because it would be red on green which might make yellow.

INCORRECT RESPONSES

(A) The black would cover up the green but not the red.

(D) Because green and red makes up the color blue.

(B) Because I don't know if you take blue away, you only have green and red left, and you keep saying black.

(A) The picture would appear black and red because the two colors together would make black, and you have only red left.

(C) Because white on black produces yellow color, I think.

APPENDIX B

CONTENT MATERIAL FOR CONCRETE INSTRUCTION

PHYSICAL SCIENCE * * * UNIT ONE * * * NAME____________________
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EXPLORATION

Interpretation: Have you ever walked across a wool rug and then touched a metal object such as the screws on a light switch. What action did you feel? Have you ever noticed what happens when you comb your hair briskly on a dry day? Have you ever noticed nylon clothes stick together when you take them out of the dryer? What do these things have in common? You will do some experiments to find out more about these.

Experimentation: Begin by tearing some paper into small pieces. Then take an ordinary hard rubber comb and bring it close to the paper. What happens? Make a record of your observation. Is there any interaction between the comb and paper? Now see if you can find a way to cause an interaction between the items in your system. Do as many different things as you can think of to cause something to happen in your system. Be sure to write down each thing you do and the results you observe.

(Experiment time)

You will now be given a rubber rod and a piece of wool. Compare its interaction with the paper to everything you have done with the rubber comb.

(Experiment time)

If you have not done so already, try to pick up the paper with different parts of the rod: i.e.; the pointed end, the blunt end, the middle.

(Experiment time)

You will now be given a glass rod and a piece of silk. Compare the interaction of the glass on the paper to the rubber on the paper. Make a record of all similarities and all differences you observe.

(Experiment time)

INVENTION

Concept: You have been working with electrical charge. Since this electrical charge is not moving it is called 'static electricity'.

Understanding the concept: Data from your exploration enable you to answer the following questions.

1. What is static electricity?

2. What does it mean to say an object is charged?

3. Why is static electricity a form of energy?

DISCOVERY

Experimentation: Find as much evidence as you can that static electricity is a form of energy. Make a record of all the evidence you find. Be sure you understand that static electricity is a form of energy.

(Evidence)

Experimentation: Suspend a pith ball with silk thread from a support. Now charge a rod with static electricity. Bring it near the pith ball. Record your observations. Why do you think your system behaved as it did?

(Experiment time)

Now charge two pith balls with the same rod. Then bring the two pith balls near each other. Record your observations.

(Experiment time)

Charge one pith ball with a glass rod and a second with a rubber rod. Then bring these two pith balls near each other. Record your observations.

(Experiment time)

Experimentation: Charge a glass rod and suspend it with silk thread from a ring stand so that it is horizontal. The glass rod is now free to move. Let the rod stop swinging before you continue. Now charge a second glass rod as you did the first, then bring it close to the suspended rod. Make a record of what you did and what happened. Try as many different things as you can think of to do to this system. You may need to recharge the suspended rod from time to time.

(Experiment time)

You are now to try the same experiment with two rubber rods. Compare what happens to your observations with the two glass rod system.

(Experiment time)

Now find out what happens when you use a system of one glass rod and one rubber rod. Use as many different combination as you need to.

(Experiment time)

Model building: You have found that when two objects that have been charged the same are brought close to each other, they will repel. This happens with two glass rods and also with two rubber rods. When you used a rubber rod and a glass rod you found that they attract each other. The glass rod and the rubber rod have different types of charge on them. Scientists have been able to find only two types of electricity. They call the type of charge on the glass rod 'positive' and the charge on the rubber rod 'negative'. Many experiments have been done which show the same results as you have found.

BACKGROUND INFORMATION

Benjamin Franklin was the man who named electric charges positive and negative. You may have heard of his famous kite flying experiment which showed that lightning is electricity. You should NEVER try this however. Franklin was very lucky that he was not hurt doing the experiment. Several men have been killed trying to duplicate his work.

DISCOVERY (Cont'd)

Observation: You are now going to experiment with an electroscope. An electroscope is an instrument that will detect static electricity. Look carefully at how the electroscope is made. Describe in your notebook everything about its construction.

(Observation)

Experimentation: Now touch a charged glass rod to the knob of the electroscope. Be sure the glass has a strong charge on it. Make a record of what happens.

(Experiment time)

Interpretation: What do you think caused the leaves to spread apart. Use the data you obtained in your previous experiments. Write a paragraph explaining what happened and why you think it happened.

(Paragraph)

Model building: The leaves of an electroscope spread because both of them are connected in one place. This causes both of them to have the same charge and thus they repel at the ends where they are not connected. When the leaves of an electroscope are spread apart it is said to be 'charged'.

Experimentation: Find a way to discharge the electroscope.

(Experiment time)

Model building: One way to discharge an electroscope is to touch it with your finger. Scientists sometimes call discharging an electroscope 'grounding'.

Interpretation: Write a paragraph telling why you think scientists use the word 'grounding' to mean discharging an electroscope.

(Paragraph)

Experimentation: Now repeat your experiment using a charged rubber rod. Remember you will now be working with negative electricity.

(Experiment time)

Model building: An electroscope will detect both positive and negative static electricity. It works the same way for both. Charging and discharging an electroscope by touching the knob of the electroscope with the rods and the ground is known as 'conduction'.

Experimentation: Find another way to affect the leaves of an electroscope with a charged rod. Charge the electroscope by conduction with positive electricity. Now bring a negatively charged rod near the knob but do not touch it. Record your observation. Why do you thihk this happened?
(Experiment time)

Prediction: Predict what will happen when you do the opposite, that is if you charge the electroscope with negative electricity by conduction and bring a positively charged rod near the knob.

(Paragraph)

Experimentation: Now perform the experiment to test your prediction.

(Experiment time)

Try as many other combinations as you can think of and explain why the electroscope behaves as it does.

(Experiment time)

Model building: The leaves of a charged electroscope will collapse when the opposite charge is brought near the knob. This phenomenon of a charge only being near an object yet still affecting it electrically is known as 'induction'.

Experimentation: Now find a way to charge a neutral electroscope without touching it with a charged rod. In other words, charge the electroscope by induction.

(Experiment time)

Model building: An electroscope may be charged by induction by grounding the knob while it is under the influence of a charge, then by releasing the ground followed by removing the inductive influence of the charge.

Experimentation: You will now investigate the properties of different substances with an electroscope. You have found that you can ground the electroscope by touching it with your finger. Try to ground it by holding different materials in your hand and touching the knob. Record each observation.

(Experiment time)

Model building: You have found that some objects such as plastic, glass, rubber and paper will not ground the electroscope. Substances such as these are known as 'insulators'. The materials that will ground the electroscope such as copper, aluminum and iron are known as 'conductors'.

Interpretation: Write a paragraph explaining how you think insulators work. Give evidence to support what you say.

(Paragraph)

Observation: You have found that electricity will move through conductors, but will not move through insulators. Find evidence of the use of conductors and insulators in as many different places as you can.

(Evidence)

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What you have learned about static electricity is important for your understanding of electriciy. Static electricity however cannot be used for most practical situations. Look up the word 'static' in the dictionary if you are not exactly sure what it means.

EXPLORATION

Observation: Examine several pieces of electrical wire. What materials do you think they are made of? What are the similarities and the differences of the wire you observed. Note these in your records.

(Observation)

Experimentation: For this experiment you will need an ordinary flashlight dry cell, a flashlight size bulb and a piece of wire. Examine the dry cell and the bulb carefully. These three objects make up a 'system'. Find a way to cause interaction in this system. What is your evidence of interaction?

(Experiment time)

Continue to experiment to find other ways to make the system interact. As you find them, make a drawing in your records.

(Experiment time)

Prediction: Each of these pictures shows a dry cell, a wire and a bulb system. The objects in the system are connected differently in each picture. Why does the system remain the same sytem? Study the way the objects in the system are arranged. Predict which of the arrangements will produce evidence of interaction. Record your prediction in your records. Make a table like the one shown. Each end of a dry cell is called a pole. Notice one pole is marked '+' and the other '-'. Do you think this may be related to the positive and negative electricity of Benjamin Franklin?

PICTURE	PREDICTION (Yes or No)	EXPERIMENT (Yes or No)
A		
B		
C		
D		
E		
F		
G		
H		

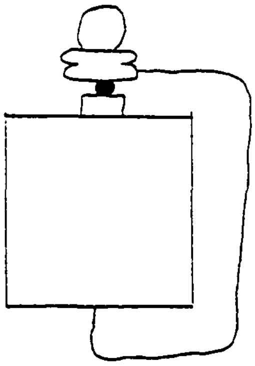
PHYSICAL SCIENCE * * * UNIT TWO * * * PAGE TWO

You are predicting whether each of the arrangements of the objects in the system will give evidence of interaction. Write 'yes' or 'no' in your table to tell whether or not you expect to find evidence of interaction. If you wish to change any of your predictions do it now.

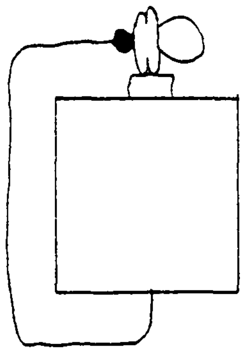
Experimentation: From now on do not change any of your prediction. You are going to do experiments with a dry cell, a bulb and a wire to test your predictions. Arrange the objects in the system just as they are shown in the pictures. Record in your table whether or not you found evidence of interaction by writing 'yes' or 'no'. Don't be concerned if you predicted wrongly for some arrangements of the objects. Figure out why you predicted incorrectly. Record what you decided about incorrect prediction.

(Experiment time)

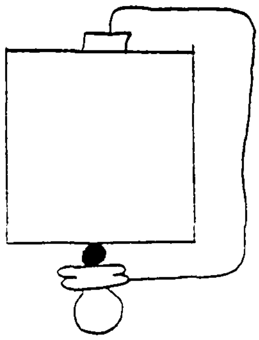
A



B



C



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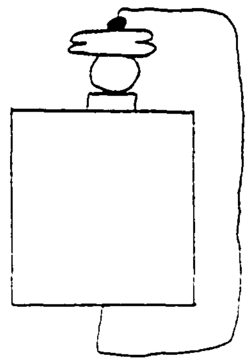
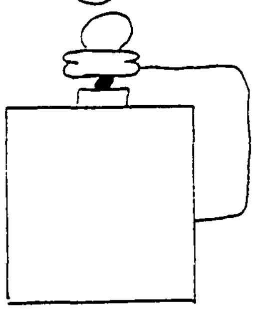
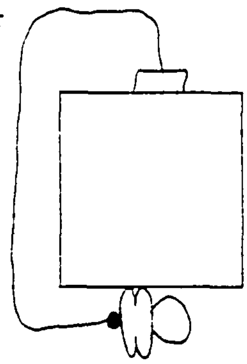


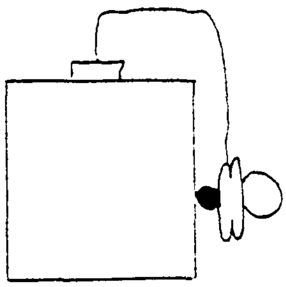
E



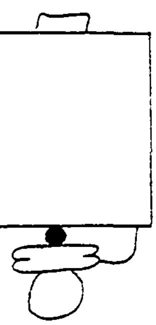
F



G



H



INVENTION

Concept: When a dry cell, a wire and a bulb are arranged so as to produce evidence of interaction the system is said to be an 'electric circuit'. The interaction of the system that produces evidence of something happening in the circuit is known as 'electrical current'.

Understanding the concept: Data from your exploration enables you to answer the following.

1. What is the evidence of interaction in your electric circuit?

2 How must the bulb be connected to the dry cell to produce electric current?

3. What is the energy source in the electric circuit?

DISCOVERY

Experimentation: Now add another wire to your system and find a way to produce the interaction. Again draw a sketch showing how the system is connected to produce electrical current.

(Experiment time)

Interpretation: What advantage does a two wire system have over a one wire system?

(Paragraph)

Experimentation: Find other ways to connect the system using two wires and draw them. Does the length of the wire affect the system? Do both wires need to be the same length?

(Experiment time)

Prediction: Do you think you can cause interaction in the system using more than two wires? Draw several sketches using three, four and more wires that you think will work.

(Drawings)

Experimentation: Now test each drawing to see if your prediction is correct. Again do not be concerned if your prediction was not correct. Try to explain any discrepancies in your prediction.

(Experiment time)

Interpretation: State a general rule about how to construct a simple circuit.

(Pagargaph)

Model building: You have found that any combination of wires and wire length will produce interaction in a circuit as long as the dry cell is connected to the bulb at each of its poles with wire. This type of circuit is called a 'simple series' circuit.

Your data enable you to answer the following questions:

1. What is the purpose of the dry cell in a simple series circuit?

2. What is the purpose of the bulb in a simple series circuit?

3. What is the purpose of the wires in a simple series circuit?

4. What is the evidence ofinteraction between the items of a system that is connected in a simple series circuit?

Observation: Examine the object given you by your teacher. What kinds of materials do you think it is made of? Why to you think the parts are arranged as they are?

(Observation)

Prediction: What do you think this object can be used for in an electric circuit? Make a drawing of this object in an electric circuit. Make a prediction about how you think it will work.

(Prediction & Drawing)

Experimentation: Now arrange an experimental circuit that corresponds to your drawing. Test your prediction. If you predicted incorrectly try to explain why.

(Experiment time)

Model building: The object you have been experimenting with is called a 'knife switch'.

Data from your experiments enable you to answer the following.

1. How does a knife switch work.

2. What is the function of a knife switch in a simple series circuit?

Experimentation: What difference does it make as to where you put the switch in your circuit? Try as many different places as you can think of to answer this question and record each observation.

(Experiment time)

Interpretation: Examine several different kinds of switches carefully. How are they like the knife switch? How are they different? Write a paragraph explaining how switches work and state a rule about the operation of switches.

(Paragraph)

Model building: In the type of circuit you have been working with it does not make any difference where you put the switch. It will control the circuit by breaking the movement of electricity. In other words it does not let the electricity move from the dry cell to the bulb. When a switch is arranged so that the electricity will move the switch is said to be 'closed'. When it is arranged so that electricity cannot move through the circuit it is said to be 'open'.

Data from your experiments enable you to answer the following:

1. What is a common feature of all switches?

2. Describe in your own words the purpose of a switch in an electric circuit.

Experimentation: Some lights, in a hall for example, are controlled by two switches, one at each end. This circuit is controlled by a pair of two way switches. How do you think a circuit with two way switches is built? Experiment with a pair of two way switches to build a working circuit.

(Experiment time)

Prediction: You may have wondered how the electricity gets from the dry cell to the bulb. You have already found that it takes two contacts with the dry cell to make the bulb light. Make a prediction about how you think the electricity moves along the wires. Talk to your classmates and see what they have predicted. Is there more than one possible explanation. If so, write them down too.

(Predictions)

Experimentation: The equipment used in your experiments so far is not good enough for you to test your prediction. For this experiment you need a vacuum tube. Do you know what a vacuum is? If not be sure you understand before you go on. The vacuum tube has four wires connected to it. Two of the wires are connected inside to a heating element. One of the other wires is connected to a large metal plate inside the tube. The plate has been painted with phosphorus and looks sort of like white paint. The other wire is connected to a small wire filament in the center of the tube. The wire filament is not connected to the metal plate.

You need to use a dry cell with much more power than the small dry cell you have been working with. The power supply used converts ordinary hosehold electricity to the kind you need, but you can think of it as a very powerful dry cell.

First connect the heating coil so that the filament will be hot. Now connect the filament to the negative pole and the metal plate to the positive pole. Observe carefully what you see in the tube. Make a drawing showing how the tube is constructed and how it is connected to the power supply. You may use the drawing supplied by your teacher to help you.

(Experiment time) (Drawing)

Interpretation: Now change the wires around. This time the filament will be connected to the positive pole and the metal plate to the negative pole. Make a drawing of the system now. Also make a record of your observation of the system.

(Experiment time) (Drawing)

Interpretation: Try to explain any differences you observed in the two arrangements of the system. Do you think the electricity is the same kind in both wires?

(Paragraph)

Model building: In order for the electricity to move something must have happened between the filament and the metal plate. You will remember that opposite charges attract each other. When the filament is hot and connected to the negative pole, the electricity is ready to go somewhere. Since the metal plate is positively charged, attraction occurs and the electricity moves from the filament to the plate. This causes the phosphorus to glow. After the electricity gets on the plate it is attracted to the positive pole of the power supply. In other words, the electricity makes a round trip. Do you understand now why you must always have two wires to make an electrical circuit?

Experimentation: You have conducted several experiments using an ordinary flashlight dry cell. You have found that a dry cell will supply electricity to light a bulb. You may be familiar with the battery in a car. It supplies electricity to light the lights, honk the horn, start the car and play the radio. Can you think of anything else the battery supplies electricity for in your car?

In this experiment you are going to try to find out how a battery works. You will need a piece of magnesium, a piece of brass, a beaker, a flashlight bulb, some vinegar and all the wire you need. Be careful not to get any vinegar in your eyes. If you do, wash them with plenty of water.

Using what you have learned about simple circuits, see if you can find a way to make the system interact. You know that the light will glow to provide evidence of interaction.

(Experiment time)

Make a drawing of your system and label all the parts in the system.

(Drawing)

Model building: You have now made a 'wet cell' that is very similar to the battery in your car.

Experimentation: Obtain several different types of metals and see what happens when they are used to make a wet cell. Which combinations of metals are the best? What happens when you use the same metal for both poles of the wet cell?

(Experiment time)

Model building: You have found that a wet cell can be made from two dissimilar metals and vinegar.

Experimentation: Chemists call vinegar an acid. Experiment with some other acids to see if they will also make a wet cell. Then try solutions of bases and salts. Note all your observations.

(Experiment time)

Model building: You have found that a wet cell can be made from two dissimilar metals and a solution of acid, base or salt. Chemists say the reason these solutions work is that there are 'ions' in the solution. The ions are small charged particles that are similar to the charged rods you used in experimenting with static electricity.

Experimentation: You may be wondering how the cell works. To find out something about a wet cell, build one of the ones that worked the best for you. (It probably is best to use brass, magnesium and vinegar.) Leave the light burning and see if you can see anything happening to the wet cell. Record everything you observe. Be sure you watch for a long enough time that you feel sure you are correct.

(Experiment time)

Model building: You have found that if you leave the wet cell hooked up to the bulb for a long enough time that one of the metals seems to dissolve in the solution and the other one seems to get larger. Scientists call the electrode that dissolves in the solution a 'cathode' and the one that gets larger an 'anode'. The cathode corresponds to the '-' pole and the anode corresponds to the '+' pose of the dry cell you have worked with.

Experimentation: Continue to let the bulb burn and observe what happens.

(Experiment time)

Model building: You found that eventally all of the cathode dissolves in the solution. When that happens the bulb stops burning. This is known as the wet cell 'running down'.

BACKGROUND INFORMATION:

You have found that different combinations of materials will cause the lamp to burn at different intensities. You might say that the brighter the lamp burns, the more power the battery has. An Italian scientist, Alessandro Volta was the first person to develop a wet cell. In his honor, the power you observed has been named 'volt'. You may have heard this word before. Ordinary household electricity is 110 volts.

DISCOVERY (Cont'd)

Experimentaion: You may have wondered if it is possible to make a wet cell with a higher voltage than you have done so far. Experiment with two wet cells to see if you can make a combination that has more voltage than a single wet cell.

(Experiment time)

Model building: You have found that when you connect two cells together in a certain way you can produce more voltage. When two or more cells are connected together in this way scientists say you have a 'battery'.

Observation: Examine an ordinary automobile battery carefully. What evidence can you find in its construction that supports the data you have collected?

(Evidence)

Interpretation: People commonly call an ordinary flashlight dry cell a battery. Write an explanation of why they are not exactly correct.

(Paragraph)

Observation: Obtain a dry cell that has been opened by your teacher. Examine it closely and sketch what you observe. How is a dry cell similar to a wet cell? How is it different?

(Observation & Drawing)

Model building: A 'dry cell' is similar to a wet cell except that it is made of different kinds of materials.

Experimentation: In this experiment you will more closely examine the movement of electricity through a circuit. You will be using an instrument designed to measure the amount of current in a circuit. The meter is calibrated in units called 'amperes'. The ampere is selected in honor of the great French scientist Andre Ampere.

Place the ammeter in your circuit of one dry cell and one bulb. Place a switch in your circuit also. Be careful to connect the '+' marked on the ammeter to the anode and the '-' to the cathode. Before closing the switch ask your teacher to inspect your circuit. Now close the switch and observe the ammeter. Make a record of how much current is flowing in your circuit. Also note how bright the bulb is glowing.

(Experiment time)

Next try to find out what happens when more bulbs are added to your circuit. Add a bulb to the circuit in such a way that all the electricity must go through both bulbs. Close the switch and make a record of the reading on the ammeter. Also note what has happened to the brightness of each bulb.

(Experiment time)

Model building: When you have twice as many bulbs in the circuit each one burns half as bright. Also two bulbs will allow only half the current to move through the circuit. It is twice as hard for the electricity to get through two bulbs as it is to move through one. Scientists call this property of the bulb 'resistance'. When two or more resistances are connected so that all the current must flow through each one it is called a 'series circuit'.

Prediction: Predict what you think the ammeter will read when you have three bulbs (three times as much resistance) in the same series circuit.

(Prediction)

Experimentation: Now test your prediction using an ammeter to measure the current.

(Experiment time)

Interpretation: Write a paragraph that explains the relationship you have found between the resistance in a series circuit and the amount of current flowing through the circuit.

(Paragraph)

INVENTION

<u>Concept</u>: Adding resistances in series to a circuit causes a decrease in the amount of current flowing in the circuit.

<u>Understanding the concept</u>: Data from your exploration allows you to answer the following questions.

1. How is a series circuit constructed?

2. What does the term 'resistance' mean in connection with an electric circuit?

3. What can you do to a series circuit to increase the amount of current flowing through the circuit?

DISCOVERY

Prediction: Now go back to your original circuit with one dry cell and one bulb. Predict what will happen when you connect two dry cells in series to power your circuit. What do you think the ammeter will read?

(Prediction)

Experimentation: Test your prediction by measuring the current in this circuit using an ammeter.

(Experiment time)

Model building: You have found when you add a second dry cell to the circuit in series that the current is doubled. Adding dry cells in series to a circuit increases the voltage of the circuit. It also increases the current flowing in the circuit.

Prediction: Predict what will happen when you place three or more dry cells in your series circuit of one bulb.

(Prediction)

Experimentation: Now test your prediction using an ammeter to measure the current.

(Experiment time)

Interpretation: Write a paragraph that explains the relationship between the number of dry cells connected in series (the voltage) and the current in the circuit.

(Paragraph)

Prediction: Now make a prediction about the amount of current that will flow in the circuit when you connect two dry cells and two bulbs in series.

(Prediction)

Experimentation: Now test your prediction by building the circuit and make a record of the reading of the ammeter. Did you predict correctly. If not, can you explain why you predicted wrongly?

EXPLORATION

Experimentation: There is another way to connect two bulbs and one dry cell other than in series that will show evidence of interaction. Find a way that is different from your series circuit. How bright is each bulb glowing in this circuit? How is this different from the series circuit of two bulbs?

(Experiment time)

Model building: The type of circuit in which each bulb is connected to each pole of a cell is known as a 'parallel circuit'.

Prediction: Predict what will happen to the brightness of each bulb when a third bulb is added in parallel to your circuit.

(Prediction)

Experimentation: Test your prediction by building this circuit.

(Experiment time)

Prediction: What do you think about the total current supplied by the dry cell in a parallel circuit? Make a prediction by comparing the current supplied by the dry cell to one bulb to what you think it will be for additional bulbs connected in parallel.

(Prediction)

Experimentation: Now test your prediction using an ammeter to measure the total current. Be sure to place the ammeter between the dry cell and the bulbs before the circuit branches.

(Experiment time)

INVENTION

Concept: In a parallel circuit all the bulbs burn equally as bright no matter how many bulbs are added. The current flowing through each branch of the circuit is the same because the brightness stays the same.

Understanding the concept: Data from your exploration allows you to answer the following questions.

1. How is a parallel circuit constructed?

2. What happens to the total current in the parallel circuit as additional resistances are added?

3. What happens to the current in each branch of the parallel circuit as additional resistances are added?

DISCOVERY

Experimentation: There is another way to build parallel circuits. This time start with your original circuit of one dry cell and one bulb. Add a second dry cell to your circuit in parallel by connecting the two anodes and the two cathodes. What happens to the brightness of the bulb?

(Experiment time)

Prediction: Predict the amount of current supplied by three or more dry cells connected in parallel to your original circuit of one dry cell and one bulb.

(Prediction)

Experimentation: Test your prediction by building these circuits.

(Experiment time)

Model building: The total amount of current supplied by two or more dry cells connected in parallel remains the same as for one dry cell.

Prediction: Predict the amount of current supplied by each of the dry cells in a parallel circuit compared to the total amount in the circuit.

(Prediction)

Experimentation: Test your prediction by measuring the amount of current supplied by each dry cell in a parallel circuit using an ammeter.

(Experiment time)

Model building: The total amount of current supplied by dry cells connected in parallel is evenly distributed among the cells.

PHYSICAL SCIENCE * * * UNIT THREE * * * NAME________________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER

Primitive men understood very little about light and sight. Of course they knew that they saw with their eyes, and that they could not see without light. Some of their ideas might seem strange to you now. For example, they did not think of light coming from objects and entering the eyes. Rather, they thought of the eyes as somehow reaching out to grasp whatever is seen. And early men thought that darkness comes because it is night!

EXPLORATION

Observation: You will begin your study of light by discovering one of the fundamental properties of light. Set up three cards with a hole punched in each. Adjust the cards so that a light beam from a flashlight shines through all three holes. Make a record of your observation.

(Observation)

Experimentation: Now remove the flashlight and look at an object through all three holes. Try different arrangements of the cards. What condition must exist before you are able to see the object through the holes in the cards? What does this tell you?

(Experiment time)

INVENTION

<u>Concept</u>: Light travels in straight lines.

<u>Understanding the concept</u>: Data from your exploration enable you to answer the following questions.

1. How does a beam of light from a flashlight travel through the holes in the three cards?

2. How can light from an object be seen through the three holes in the cards?

3. What effect on seeing an object is produced when the holes are not in a straight line?

DISCOVERY

Interpretation: Suppose you look at an object such as a pencil. You see it because light travels in a straight line from the pencil to your eyes. You see it there in front of you. You reach out and can touch it. This evidence shows that light travels in straight lines. If light did not travel in straight lines you would not be able to touch it. Things would not actually be where you see them with your eyes. Write a paragraph giving your reaction to this statement.

(Paragraph)

Now consider another piece of evidence. A simple pinhole camera will allow light to form an image on the film. If light did not travel in straight lines it would be impossible to form an image on the film. This is proof that light travels in straight lines. Write a paragraph giving your reaction to this evidence.

(Paragraph)

Now start with the assumption that light travels in straight lines. Use this assumption in all your explanations and predictions about light. So long as your assumption does not lead to contradiction it must be right. Write a paragraph giving your reaction to this statement.

(Paragraph)

Experimentation: You need a perfectly flat mirror. Such a mirror is called a 'plane' mirror. See if you can figure out why. A mirror about 10 cm. by 15 cm. is about right. You also need a piece of cardboard. Stand the mirror on end on the paper. Draw a line on the paper to represent the mirror. Now place three straight pins in a straight line as shown in the drawing.

Be sure the line makes an angle with the mirror. That line should touch the line representing the mirror. Now move to the side of the mirror opposite to where the pins are. Look into the mirror. You should see reflections of the three pins all in a straight line. You are seeing light leaving the mirror. That is reflected light. Stick three pins in the cardboard so they line up exactly with the reflections of the pins. Draw a line through the pin holes. That line should intersect the line which represents the mirror. You now have two lines which touch the mirror line. Those lines should also touch each other. Where do they touch?

(Experiment time)

Interpretation: The diagram you drew on your paper are your data. The data represent lines and angles. About the only way to interpret lines and angles is to measure them. What can you measure here? What do you need to know to make those measurements?

Draw a line perpendicular to the point where the rays intersect the mirror. This line is called a 'normal'. Make the measurements of the angles from the normal. Make a record of your data.

Experimentation: Get a clean piece of paper. Make the measurements again. Use a different angle between the pins and the mirror. Compare your results with those of your friends. Remember the diagram you draw is your data.

(Experiment time)

Interpretation: The measurements you have made have told you something very definite. You have just found an event that happens over and over again. In other words the data are reproducible. You and your classmates should make a careful statement of your finding. In making that statement use 'entering light' for the light striking the mirror from the pins. Use 'reflected light' for the light leaving the mirror. Be sure to make a careful record of your statement about entering light and reflected light.

(Paragraph)

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INVENTION

Concept: You have found that the angle of the 'entering light' is always equal to the angle of the 'reflected light'. This relationship is known as the 'Law of Reflection'.

Understanding the Concept: Data from your exploration enable you to answer the following questions.

1. How do objects that are smooth and shiny reflect light differently than objects that are rough and dull?

2. How are light rays reflected from a smooth surface?

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DISCOVERY

Experimentation: You have found that when light is reflected it follows certain paths. You will now do another experiment to help you understand how light is reflected. Doctor Albert Einstein said that Nature is not mischievous. He simply meant that there is a pattern to what happens in the world. In the experinemt which follows, you will find a pattern for light reflections.

You need a smooth, hard surface. A smooth door or other wooden, tiled or glass surface will do. You also need a golf or tennis ball. Lay a large piece of paper in front of the surface. Be sure the surface is perfectly smooth. Roll the ball into the hard surface. Do not roll it straight into the surface, rather use an angle. Mark the point at which you start the ball. Concentrate upon the point where the ball strikes the surface. Roll the ball into the surface enough times so you can mark the point it strikes. Always start the ball at the same point. After you know where the ball strikes draw a line between that point and the starting point.

Now concentrate upon what happens to the ball after it hits the surface. Watch the ball leave the surface several times. Watch it until you can draw a line that shows its path as it leaves. Now draw a line on the paper to represent the surface. That line should go through the point where the ball hit the surface.

(Experiment time)

Model building: You now have a diagram which represents your experiment. Your diagram is your data. What measurements can you make on it? Study your diagram. What does it tell you about how the ball was reflected from the surface? What does the answer to the last question tell you about how light is reflected? Write a paragraph about this model you have built about the reflection of light.

(Paragraph)

Prediction: You have built a model about the reflection of light from a smooth surface. You have found that the ball will bounce off the surface at the same angle at which it hit the surface. Now place a piece of soft material in front of the hard surface. Be sure the material is thick and its surface irregular. Predict what will happen if you roll the ball into the irregular material. Then test your prediction.

(Prediction & experiment)

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Interpretation: You have found that light will bounce off a hard surface according to a pattern. Compare that pattern to the way light is reflected from a mirror. How are those patterns alike? How are they different? To find the pattern you bounced the balls off of a hard surface. To make the balls move, you gave them energy. Light is energy. What type of rule can you make about the reflection of energy?

(Paragraph)

Experimentation: You are becoming familiar with the image produced by a plane mirror. You are now ready to examine the image more closely. Where is the image that you see? Is it really in the mirror. The following experiment will give you the data you need.

Stand a mirror on a piece of graph paper. Now draw a triangle on the graph paper in front of the mirror. It should be a scalene triangle. Now look at the triangle in the mirror. What you see is the image of the triangle. Where does the image appear? Does it appear as far behind the mirror as the original is in front of the mirror? Is the image larger or smaller than the object?

(Experiment time)

Model building: The image that is reflected appears to be just as far behind the mirror as the object is in front of the mirror. The image appears to be the same size as the object.

Experimentation: What do you observe about the relationship of the object to the image. Hold your right hand up to the mirror and observe the reflection. Is the reflection like your right or your left hand?

(Experiment time)

Model building: The image reflected from a plane mirror is reversed from side to side from that of the object. This image is called a 'virtual' image as the light does not pass through the apparent position of the image. Be sure you understand what a virtual image is and are able to describe how it is produced.

Interpretation: Not all surfaces are smooth and shiny. You are aware that most surfaces are rough. Does reflection occur from rough surfaces? You may have seen photographs of the surface of the moon. Is it smooth or rough? The moon and the planets shine by reflected light. How is light reflected from such a rough surface. Write a paragraph explaining why you think you are not able to see an image reflected from a rough surface.

(Paragraph)

Model building: The Law of Reflection is true even for rough surfaces. Due to their irregularity, however, no distinct pattern is reflected. The light rays are scattered in many directions. This is known as 'diffusion'.

EXPLORATION

Observation: Place an object such as a pencil in a beaker of water. What do you observe. How does the object appear at the water line?

(Observation)

Experimentation: In this experiment you need cardboard, pins, and paper just as you did in the mirror experiment. You also need a piece of thick glass. Any thickness will do but the thicker the better. Two sides of the glass should be parallel.

Set the glass on the paper. The paper should be fastened to the cardboard. The pins should be in a straight line. The line should make an angle with the straight side of the glass on Side A. Now look through the glass from Side B. Look at the pins through the glass. Stick three pins in a line on Side B that line up with the pins on Side A. Be sure you are looking through glass when you line up the pins on Side B.

(Experiment time)

Now draw a line around the glass with a pencil. Remove the glass and the pins from the cardboard. Connect the pin line on Side A to the glass. Do the same for Side B. Now draw a third line inside the glass outline from the points where these lines touch the glass.

(Experiment time)

Interpretation: Your diagram is your data. What happens to the light ray as it enters the glass? What happens to the light ray as it leaves the glass? What is the relationship of the light ray on Side A to that on Side B? Write a paragraph answering these questions. Use a normal to make your measurements.

(Paragraph)

INVENTION

Concept: The bending of light rays as they move from one medium to another is known as 'refraction'.

Understanding the concept: Data from your exploration enable you to answer the following questions.

1. How is light controlled by glass?

2. How will light be refracted when it moves from air to glass?

3. How will light be refracted when it leaves the glass and moves back into air. (The two glass/air surfaces must be parallel.)

4. How are the two rays of light in air related?

DISCOVERY

Interpretation: You have discovered that light is refracted by glass. Do you think you can depend on what you see when you look through an ordinary window pane. Consider the following:

1. In an ordinary window pane how are the two surfaces related?

2. How does the direction of the entering light compare with the direction of the light leaving the glass?

3. How is the leaving light ray a continuation of the entering light?

Write a paragraph explaining what distortion looking through an ordinary piece of window glass has on what 'really' is seen. Is this error enough to be of practical significance. Under what conditions is this error the greatest and the least?

(Paragraph)

Prediction: Examine a piece of glass. Notice that it is heavier than air. How do you think density of a material affects light? Water is heavier than air also. Do you think water will refract light? Make a prediction.

(Prediction)

Experimentation: Now test your prediction. Obtain a small rectangular aquarium. Be sure that it is clean. Then fill it with water. Use the light from a slide projector as a source of light. Position the light at an angle to the side of the aquarium. You should be able to see the path of the narrow beam of light both in the air and in the water. First examine the refraction at the point where the light enters. Is it refracted away from or toward the normal? Does this agree with what you have learned so far? How is the light refracted as it goes from the water to the air? Does this agree also?

(Experiment time)

Model building: The refractive properties of a material depend on their densities.

Experimentation: There is another interesting relation between light and the surface of two different mediums. For this experiment you will need to use your aquarium and projector light source again.

The diagrams show an aquarium filled with water as seen from the top. First have a beam of light entering the aquarium with a very large angle. Notice the light is refracted as it enters the aquarium and again as it leaves the aquarium. This is as you expect from your previous experiments.

Now decrease the angle between the light source and the normal. What do you observe?

Model building: When the light tries to leave the aquarium at a large angle from the normal it is all reflected back into the water. This is known as 'total internal reflection'.

The angle at which total internal reflection occurs between two given mediums is known as the 'critical' angle for those mediums. For water and air this angle has been measured to be about 47°. For glass and air the angle is about 42°.

BACKGROUND INFORMATION

You know that light can be refracted. You also know another term for refraction. This property of light is useful in making glasses. An entire industry is built around refraction. An opthalmologist is a physician who specializes in treating eye diseases. Often this physician treats eyes that need only glasses. Refraction is then used to decide what kind of glasses are needed. An optometrist also uses refraction to decide what type of glasses people need. An optometrist or opthalmologist can decide what kind of glasses are needed. The glasses are made by an optician. That person uses the refraction model to prepare the glasses that are prescribed.

The origin for all three of these position comes from the word optics. Optics is the science that deals with light. You built models of reflection and refraction using lines and angles. That type of optics is called geometrical optics. Figure out why. You still don't know how refraction is used in making glasses. Again you need data. So you are asked to do an experiment.

DISCOVERY (Cont'd)

Observation: You will need a special object to find out more about how eyeglasses work. That object is called a lens. You also need a flat piece of glass. Examine the two objects carefully. Make a record of how they are alike and how they are different. The shapes of the two objects are probably different. In addition there is one main difference. Be sure you find that main difference.

(Observation)

Experimentation: Use the lens to examine your finger. Does your finger look larger or smaller through the glass. Examine several other objects. Sometimes a lens such as this is called a 'magnifying glass'. Do you see why?

(Experiment time)

There is something else you can do with a lens that you may not have done before. Find a source of light such as an electric lamp. Then hold the lens out in front of a smooth, light-colored surface such as a white cardboard or piece of paper. The surface should be in rather dim light. Move the lens back and forth until you observe something on the card. What do you find?

(Experiment time)

Observation: You are able to produce an image on the cardboard. Look at it carefully. Is it in color or black and white? Is it smaller or larger than the object? Is the image erect or inverted? Where is the lens located. Is there one place where the lens can produce the clearest image?

(Observation)

Experimentation: Repeat the experiment using the flat piece of glass. What do you find? Previously you were asked to find the main difference between the glass and the lens. What was that difference? That main difference between the glass and the lens is why this lens is a convex lens. What does the convex lens do that a flat piece of glass does not do?

(Experiment time)

You know flat glass refracts light. You also know the convex lens refracts light. The evidence you have tells you they refract light differently. The flat glass has the same thickness all over. The thickness of the convex lens is not the same all over. How does the thickness of the glass control how light is refracted by it? You need to do another experiment. Use the glass blocks you used in the refraction experiment. You have data on your diagram which tells you how much one block refracts light. Use two blocks. Put two of them together. Do the experiment with the pins. How did increasing the thickness of the glass change how it refracted light?

(Experiment time)

Model building: You now know how light refraction is controlled by the thickness of glass. Remember a convex lens has many different thicknesses. Use that fact and the data you got from using two glass blocks. Build a model that tells why you get an image on a card with a convex lens. This image is called a 'real' image because the light passes through the image.

EXPLORATION

Experimentation: You have found that a lens will produce an inverted real image on a white card held behind the lens by refracting the rays of light. You are ready to begin investigating the nature of that image. You will begin by doing an experiment to collect some data about the image.

You need your convex lens and a white card. You also need a measuring stick. A meter stick is probably best. You are going to study the distance the image on the card is from the lens. You are going to do that when objects are far away. In this experiment any object that is 10 meters away is called far away.

Measure the distance from the lens to the image on the card. Take ten measurements from objects that are ten different distances away. Be sure those distances are always 10 meters or more. Make the measurements when the image on the card is the clearest. Record those distances. All of those distances have a common property. Determine what that property is.

(CAUTION: If this experiment is done outside be very careful of the extreme danger present of looking through the lens at the sun. DO NOT LOOK DIRECTLY AT THE SUN.)

(Experiment time)

Now turn the lens around and make 10 more measurements. What difference does it make which way the lens is positioned?

(Experiment time)

INVENTION

Concept: The distance from a lens to the image it produces when the object is far away (incoming rays parallel) is known as the 'focal length' of the lens.

Understanding the concept: Data from your exploration enable you to answer the following questions.

1. How is the distance from the lens to the image on a card affected when different objects are far away but at different distances?

2. Is the image always inverted, always erect, or sometimes inverted and sometimes erect?

3. What difference does it make which side of the lens is toward the object?

4. How are the focal lengths on each side of a lens related?

DISCOVERY

Experimentation: Measure the focal length of four different lenses. Be sure each one has a different thickness. How does thickness affect focal length?

(Experiment time)

Obtain two lenses which have the same focal length. Place one on top of the other. Tape their edges together. Measure the focal length of that combination. How does the focal length of the combination compare to the focal length of each of them?

(Experiment time)

Model building: You have found that the thickness of a lens determines its focal length. The thicker the lens, the shorter the focal length. It is possible to double the thickness by using two lenses in combination. You have also found that the amount of light entering the lens has no affect on the focal length. The focal length is a distinctive property of any given lens.

Interpretation: A convex lens forms an image when the lens is at the proper distance from the surface on which the image is to be formed. When the image is sharp and clear it is said to be in 'focus'. Write a paragraph explaining what you must do to focus a camera lens.

(Paragraph)

Experimentation: Now you will turn your attention to the size of the image. You may have noticed that when the object is far away the image appears to be smaller than the object. Is there a way to make the image larger than the object? To do this you will need an object which is very bright. Try the filament of an electric lamp in a darkened room. Next measure the distance from the object to the lens when the image is on a surface that is far away. What does this measurement tell you?

(Experiment time)

Now see if there is an arrangement that will produce an image that is the same size as the object.

(Experiment time)

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Model building: You have found that the image size is related to the object distance. The image size will decrease as the object distance increases. The two diagrams below may help you understand why.

In diagram A the object is far away from the lens. Two rays of light emitting from the point of the arrow are shown as they pass through the lens. The top ray is the one that is parallel to the center line. You know that as it enters glass it will be refracted by a certain amount. As it leaves the glass it will be refracted again by that amount. The bottom ray of light passes through the center of the lens. Since it enters and leaves perpendicular to the surface of the glass it is not refracted. The image is formed where these two lines intersect. The image is much closer and therefore smaller than the object.

In diagram B the object is close to the focal length of the lens. The same two rays of light are shown. Trace them and be sure you understand what is happening. Do you understand why now the image is far away and larger than the object?

Interpretation: Make a diagram similar to the ones above that will show the position of the image, object and lens when the object size and the image size are the same. What can you say about the object distance and the image distance of this arrangement? You may need to gather some data using a lens to answer this question.

(Diagram)

Experimentation: Try to produce a real image when the object is inside the focal length. What do you observe?

(Experiment time)

Model building: When the object is inside the focal length a lens will not produce a real image. Rather it produces a virtual image that is erect and larger than the object.

Observation: Examine a camera closely. You already know that a camera makes use of a lens to focus an image. Where does the film go in the camera. How is the lens focused?

(Observation)

Now examine closely a model of the human eye. How is it like a camera? Where is the lens located? Where is the image produced? What controls the amount of light entering the eyes?

(Observation)

Model building: The human eye is very much like a camera. The lens focuses an image on the back of the eye that corresponds to the film in a camera. This part of the eye is called the 'retina'. The image on the retina is inverted. Your brain decodes this image and you see things right side up. The iris can change size to vary the amount of light entering the eye.

Interpretation: The image is focused in a camera by moving the lens back and forth. The lens of your eye does not move back and forth. Write a paragraph explaining how you think your eye focuses an image on the retina. Remember what your data has shown you about the relationship between the thickness of a lens and its focal length.

(Paragraph)

EXPLORATION

Observation: Up to this point you have investigated the properties of light without paying much attention to its color. What is the nature of colored light? How are colors produced. You are going to do some experiments to find out more about colored light.

Use a bright light source with a narrow beam. A slide projector is a good strong light source. You can make a slide so that the projector will produce a narrow beam. Shine the narrow beam of white light through a prism and observe what happens. What colors do you see. How many different colors do you see? Are these colors the same as you see in a rainbow? Where do you think the colors come from?

(Experiment time)

Model building: A prism will change white light into many different colors of light. The next experiment will give you additional data for your model of color.

Experimentation: You will need three slide projectors for this experiment. Prepare to shine them on a white surface such as a movie screen. You will also need several pieces of colored cellophane (blue, red, and green) so the projectors can be sources of red, blue and green light. You can make a slide with several pieces of cellophane so that the colors are fairly deep.

Arrange the projectors so that they shine on the same white surface. Turn the red and the blue projectors on together. What color do you see? You may have called this color purple. The proper name for it is magenta.

(Experiment time)

Now try blue and green. You might call this blue-green, but its proper name is cyan.

(Experiment time)

What happens when you use red and green. The name for this color is yellow.

(Experiment time)

Model building: You have been creating new colors by addition of color. When you add two colors together you produce a color that has some of the properties of each of the original colors.

Experimentation: Now turn on all three projectors. You will be adding red, blue and green together. What do you observe? What does this tell you? What do you think white light is now?

INVENTION

Concept: White light is a combination of three colors: red, green and blue. These colors are known as 'primary' colors.

Understanding the concept: Data from your exploration enable you to answer the following questions.

1. What does a prism do to white light?

2. How can white light be produced?

3. What does the addition of two primary colors produce?

DISCOVERY

Experimentation: Why is an apple red? Why is the grass green? You do not have enough information to answer these questions. You know a way to learn more about color. You can find out for yourself--experiment.

You should do this experiment in a darkened room so that no outside light can spoil your experiment. You need some pieces of colored paper. You may also use colored cloth. You need a source of colored light. Obtain slide filters of different colors and use a slide projector to produce colored light. Select a piece of paper that appears red when seen under white light. Now examine it under red light. What color does it appear to be?

(Experiment time)

Now examine the red cloth under other colors of light. Try blue and green. How does it appear under each of these light?

(Experiment time)

You know that blue and green are primary colors. Try a yellow slide in the projector. What color does the cloth appear now?

(Experiment time)

Interpretation: Write a paragraph explaining why you think you are not able to see a red cloth in blue and green light but it appears red in yellow light. Recall how yellow light is made. If you don't remember, check your records. What color does red cloth appear if there is no light shining on it? How does red cloth seem to affect the color of red light that falls on it? How does red cloth seem to affect the color of blue and green light? What evidence is there that red cloth acts as a prism and that you see only the red part of the light coming back from the cloth?

(Paragraph)

Model building: You have just built a model for red light. Your model states that an object appears red because it reflects red light to your eyes but absorbs (does not reflect) blue and green light. The red object appears red under yellow light because yellow light is a combination of red and green.

Prediction: Use the model you have built for red light to predict what will happen when you repeat the experiment using a green object. Predict for green, red, blue, and yellow light.

(Prediction)

Model building: You have discovered that white light is a combination of three primary colors. It is produced by adding red, blue and green. This is the addition model of color and uses the 'scientists' primary colors red, blue and green. You have also learned that objects appear a certain color by subtracting all the other colors from white light. The filters you have been using in the slide projector work by subtracting light. You will now learn more about the subtraction model of color.

Prediction: What color do you predict will result when some blue food coloring and some yellow food coloring are mixed together. Remember by mixing these together you will need to use the subtraction model of color.

(Predition)

Experimentation: Test your prediction by performing the experiment. If you predicted wrongly be sure you can explain why.

(Experiment time)

Prediction: Now use your subtraction model of color to predict what will result when you mix red food coloring and yellow food coloring.

(Prediction)

Experimentation: Now test your prediction. Explain any discrepancies.

(Experiment time)

Prediction: Use your subtraction model of color to predict the results of mixing red food coloring and blue food coloring.

(Prediction)

Experimentation: Now test your prediction.

(Experiment time)

Model building: Colors can be obtained by mixing three colors red, blue and yellow. These are sometimes called the artists' primary colors. You may have used them in art class. It is the basis for the artists' color wheel. Artist's base their color combination on the subtraction model of color.

Interpretation: You have learned that white light is a combination of color. Black is sometimes defined as the abscence of all color. Write a paragraph explaining how you would produce black using the artists primary colors.

(Paragraph)

Experimentation: Now try to produce black according to your paragraph. Is it possible to produce black using the scientists primary colors? Do an experiment to answer this question?

(Experiment time)

BACKGROUND INFORMATION

Three different but related terms are used to describe color. Hue indicates the name of the color. It is best defined by example: blue, indigo, tan and bronze are all hues. Brightness is the relative intensity of light and may be used to describe white light. Saturation refers to the purity of the color. Colors that do not contain any white light are said to be saturated.

PHYSICAL SCIENCE * * * UNIT FOUR * * * NAME_______________
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER

One of the really enjoyable parts of our lives is the sounds we hear. The sounds of friends voices, music, wind and rain against a window, and laughter are all good sounds. Other sounds such as the crash of a broken glass, the sound of a forest fire, and cries of pain are not pleasant sounds. Sounds often tell us when those around us are happy or sad. When someone is whistling or humming we usually think he is happy. The sound of someone sobbing also tells us something.

EXPLORATION

Interpretation: Sounds can also be useful to us. The sound of an alarm clack, a radio or someone's voice can wake us in the morning. The sound of a bell often tells us when something is about to begin. Suppose you ask someone a question. You probably depend upon the sound of that person's voice for a reply. When you listen to a radio you depend completely on sound to get the message. Listed below are seven sounds. Where might you be and what might be happening when you hear each of them?

1. A siren.

2. The honk of a horn.

3. A knock on a door.

4. A tap on a window.

5. A loud, booming, crashing sound from the sky.

6. A door bell.

7. A sizzling, sputtering sound.

Experimentation: You may be wondering about what is the nature of sound. How does sound reach you? Where does it come from? Where is it made? You will do some experiments to find out some things about sound.

Begin by placing your hand on your throat. Speak and then hum. Stop and then begin again. Record what you felt while speaking. Now record what you felt while humming. How did those two 'feelings' compare? What was the difference in feeling when you stopped?

(Experiment time)

Now repeat the experiment by placing your hand on another person's throat. How do these data compare to what you received by feeling your own throat? Record your data.

(Experiment time)

Place your hand on a piano that is being played. Leave your hand on the piano and ask the person to stop playing. What does this experiment tell you? Record your data.

(Experiment time)

Repeat the experiment with another musical instrument. Record what you find.

(Experiment time)

Experimentation: You will now do some experiments using a tuning fork. Any tuning fork will do. To make a tuning fork sound you strike it. Never strike a tuning fork with anything harder than wood. Metal, hard plastic or glass can harm a tuning fork. Hold the tuning fork in one hand. Strike it. Immediately hold it near your ear. What did you find out? Record these data.

(Experiment time)

Why do you think striking the tuning fork produced the sound? Strike the tuning fork again. Touch the fork with your fingers. What do you feel? Describe these data carefully.

(Experiment time)

Pluck the strings of a guitar. Why do you think the guitar makes a sound? Touch the strings with your finger as they produce sound. What do you feel?

(Experiment time)

Model building: Each of the previous investigations gave you data. Some of the data were different. Among all the investigations something was the same. What was it? That similarity among all the investigations is one of the most important properties of sound. Discuss with your classmates and your teacher what that property is. Make a record of that property. You are building a model of sound.

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INVENTION

Concept: Sound is produced by something vibrating.

Understanding the concept: Data from your exploration enable you to answer the following questions.

1. How is sound produced from a person's voice?

2. How is the sound produced by other people similar to your own?

3. How is the sound of a piano produced?

4. How do other musical instruments produce sound?

5. How does a tuning fork produce sound?

DISCOVERY

Experimentation: You have found that a tuning fork produces a sound by vibrating. Fill a container with water. Strike the tuning fork. Immediately place the tuning fork in water. What did you observe? Make a careful record of your data.

(Experiment time)

Tape a ping pong ball to a string. Have someone hold the string. The ball should hang straight down. Strike the fork. Immediately place the fork against the ball. What observation did you make? Describe your data.

(Experiment time)

Now hook a small bell to a dry cell. What evidence can you find that the vibration property of sound is present?

(Experiment time)

Interpretation: Why in some better stereo systems do they have more than one speaker? How are these speakers different? What evidence do the speakers provide about the vibration property of sound you found?

(Paragraph)

Experimentation: You have observed that the strings of a guitar produce sound by vibrating. Now turn your attention to the way the guitar produces high and low sounds. Strum the string of the guitar that produces low sounds. Then strum the string that produces high sounds. What difference do you observe?

(Experiment time)

Model building: You have found that high sounds are produced when the strings vibrate very fast Similarly low sounds are produced when the strings vibrate slowly. This rate of vibration is known as 'frequency'. Musicians refer to the highness or lowness of a note as the 'pitch' of the note. Pitch and frequency both refer to the same thing about a sound.

Interpretation: The low pitches are produced by long wires on a piano. The high pitches are produced by short wires on a piano. Write a paragraph explaining the relationship between the length of a wire and the frequency with which it vibrates.

(Paragraph)

EXPLORATION

You have been doing a lot of experimenting that has shown you that sound is produced by something vibrating. The evidence of interaction is given to you by your ears. When someone plays the guitar you hear the music. How does the sound get from the guitar to you? How does sound travel from one place to another? Do some experiments to find out.

Experimentation: Have a friend strike one end of an iron bar while you keep your ear close to the other end. Does the sound travel through iron?

(Experiment time)

Place your ear next to some piece of metal on a school bus or a car that has the motor running. Can you hear the motor better now? Does sound travel through metal or air best?

(Experiment time)

Interpretation: Does sound travel through some materials better than others? Do you make more noise as you walk on a wooden floor or on a floor covered by thick carpet? Why do you think a concert hall has heavy thick drapes hanging at the back of the stage? Write a paragraph answering these questions.

(Paragraph)

Experimentation: Now build a small string telephone system. You need two metal cans, a long piece of string, and two buttons or metal pieces. The string should be about 20 meters long. Cut off the tops of the cans. Make a hole in the bottom of each can. Put the string through the hole in each can. Tie it to the button. Stretch the string tightly between you and your partner. One of you hold one can to his ear. The other one speak clearly into the other can. What happens?

(Experiment time)

Interpretation: Suppose you were to speak into one of the cans without the string attached. Suppose your partner holds a second can to his ear. Do you think the system will work without the string? Write a paragraph explaining what you think would happen. Then test your prediction by performing the experiment.

(Prediction)

Model building: The explorations you have done have given you data about a second property of sound. Those data are related to how sound travels. How did sound travel between you and your partner? Build a model about this second property of sound using the evidence you have gathered.

Experimentation: Now find the difference between loud and soft sounds. Experiment with a guitar using a note of one pitch. Make a loud and soft sound. Place a piece of folded paper on the string to help you. When you have found how loud and soft sounds are produced make a record in your notebook.

(Experiment time)

Model building: The size of the vibration determines the loudness of the pitch. Scientists refer to this as the 'amplitude' of the vibration. An object that vibrates with a large amplitude produces louder notes than an object that vibrates with a small amplitude.

BACKGROUND INFORMATION

It is possible to distinguish between two different musical instruments that are playing the same pitch and at the same loudness. This property which allows you to distinguish the quality of different sounds is known as 'timbre'.

Interpretation: In some of the old Western movies you may have seen an Indian scout with his ear to the ground listening for the sounds of far off horses or buffalo. What do you think of this idea? Write a paragraph explaining why you think the scout did this.

(Paragraph)

Experimentation: You might try to hear a far off automobile or other sounds similar to the Indian scout by putting you ear to the ground.

(Experiment time)

INVENTION

Concept: Sound travels from one place to another through a medium

Understanding the concept: Data from your exploration allow you to answer the following questions.

1. What kinds of materials will sound travel through?

2. Will sound travel through some materials better than others?

3. Why is the string necessary in your telephone system?

DISCOVERY

Prediction: You know that sound is produced by vibrations. The vibrations of a tuning fork, for example, travel through the air and reach your ear. Without air, what would carry these vibrations to your ear? Think of a way to prevent the sound from traveling from a tuning fork to your ear? Do you know what a vacuum is? If not look up the word in a dictionary. Write a paragraph predicting what you think you need to do to stop sound from traveling.

(Prediction)

Experimentation: You are now ready to test your prediction. Suspend an electric doorbell inside a bell jar. Connect the bell to a dry cell. When you close the circuit are you able to hear the bell? Explain why you can hear the bell.

(Experiment time)

Now use a vacuum pump to remove the air from the jar. Close the circuit as the air is pumped out. Record your observations. Did you predict correctly?

(Experiment time)

Measurement: You have discovered that sound will travel through solids, liquids and gases but not through empty space. You may be wondering how fast sound travels. You can do an experiment to find out how fast sound travels in air.

In this investigation you need to measure time. A stopwatch is useful but not necessary. Perhaps someone in your class has a watch with a second hand. That, too, would be useful but not necessary. You can count in such a way that time can be measured. If you count "one, one thousand; two, one thousand; three, one thousand" you will use about three seconds. Practice using the counting way of measuring time. If your classroom clock has a second hand, compare your counting to it. Practice until you feel you can measure time quite well by counting.

Stand about 200 to 250 meters away from a large, straight wall. The side of a building will do. Just be sure sound can travel straight toward the wall. You also need something to make a short, loud sound. As soon as the sound is made start counting. Continue to count until you hear the sound come back to you. The reflection of sound off a smooth surface is called an 'echo'.

Model building: The experiment you have just finished gave you data about the speed of sound in air. Scientists have measured it at about 335 m/s at $0^{\circ}C$. They have also found that the speed of sound in air increases about 60 cm. per second for each Celsius degree of temperature rise.

Prediction: You have built a model about the reflection of sound from a smooth surface. You have found that sound will bounce off the surface at the same angle at which it hit the surface. Now make a prediction about what kind of an echo you will get when you try to bounce sound off an irregular soft material.

(Prediction)

Interpretation: Echoes are not wanted in music halls and other large rooms. To avoid those echoes, large, heavy drapes are often hung. The data you obtained from doing your experiments on echoes explain why drapes cut down echoes. Write a paragraph explaining that you understand this idea.

(Paragraph)

EXPLORATION

Experimentation: You have found how sound is produced. You have also found what is necessary for it to travel. You have built a 'model' of sound. The next experiment will allow you to test that model.

You need a tuning fork. You also need something proper to strike it with. You need three partners in this experiment. Begin by striking the tuning fork and listening to it. You all four now know what it sounds like. Two of the group now turn around so they cannot see the other two who have the tuning fork. They also should put cotton in their ears and hold their hands tightly over them. Now the two persons having the tuning fork should move away from the others. Next they should strike the tuning fork. The first pair should now try to tell when the tuning fork was struck. Now change places and repeat the experiment. Make a record of your findings.

(Experiment time)

You don't need the cotton in this part of the experiment. Two of the group should take the tuning fork into the hall and strike it. The second two persons should stay in the room away from the door. The pair in the room should knock on the door when they hear the tuning fork. Now the pairs should exchange places and repeat the experiment. What did you find out? Record your findings.

(Experiment time)

Model building: Your experiments have given you data about a third important property of sound. You have already built a model about how sound is produced, a second model about how sound travels, now build a third model that will complete your description of sound.

INVENTION

Concept: Sound exists only when it is perceived.

Understanding the concept: Data from your exploration enable you to answer the following questions.

1. What does sound mean to a person who does not hear it?

2. How does sound depend on the person perceiving it?

DISCOVERY

Interpretation: A boy is listening to music through a set of head phones and a girl is standing nearby. The boy says he is listening to music. The girl says she doesn't think he is. How does the girl's answer compare with the data from your experiments? Why would the girl say she didn't think he was listening to music? Write a paragraph explaining this idea.

(Paragraph)

Interpretation: According to the property of sound you just invented, there is no sound to a deaf person. Your data support this idea. Explain why. The first property of sound you invented is useful to a deaf person. Why can a deaf person use the first property in your model and not the last?

(Paragraph)

Interpretation: Imagine that on a certain day you visit a forest. You see a huge dead tree that is just about to fall over. You leave the forest just at dark and return just at daylight. You notice that the tree is now on the ground. It has fallen over during the night. Use your sound model and decide whether or not the tree made any sound when it fell.

(Paragraph)

Model building: You know that in order for something to happen energy is required. You use energy to run, energy to keep warm, and energy to breathe. The lights on a car use energy. Does sound require energy? Write a paragraph explaining that you understand that sound is a form of energy.

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EXPLORATION

Observation: Examine the object given you by your teacher. What kind of material do you think it is made of. Now examine some of the other objects given you also. How are the objects different? How are they the same?

(Observation)

Experimentation: Experiment with these objects to determine how they behave. Make a record of your findings.

(Experiment time)

Model building: The iron bar which will attract all the other iron pieces is called a 'magnet'.

Experimentation: Experiment with your magnet to see what kinds of materials it will pick up. Use all kinds of materials. Use metals, glass, cloth, wood, plastic and any other material you have. Use different kinds of metals too. Use iron, copper, aluminum and any other metal you can find. Make a record of the different kinds of material the magnet will pick up.

(Experiment time)

BACKGROUND INFORMATION

The discovery of magnetism seems to have come about by accident. It is not really known exactly how magnetism was discovered. The ancient Greeks wrote about magnets some 2,500 years ago. It is also very probable that the Chinese discovered magnetism about that time also. The story is told that magnetism could have been discovered like this. A long time ago a shepherd tied a piece of metal to the end of his staff so that it would not wear away as he walked across the hills. One day he noticed that as he placed his staff near a grayish rock he felt a strange pull on the staff. Other legends are also told that may or may not be true. You might want to look in an encyclopedia to find out about some of them.

The origin of the name 'magnet' is also unclear. The legend exists that the first magnets were found in an area of Greece known as Magnesia or Magnetes. Other reports say the name of the first man to find magnetism was Magnes. Magnets were also called 'lodestones'. The word lode is an old English word meaning 'course'.

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Interpretation: You already probably know quite a bit about magnetism. Think about magnets before you continue your study. Can you find anything around your home or school that works by magnetism? What kind of magents are you familiar with? How do they behave? Do magnets always attract?

Experimentation: You have found that magnets will attract iron. Begin by experimenting with a bar magnet and some iron filings. The bar magnet should be covered with a piece of paper to make it easy to clean. Place the magnet in some iron filings. Make sure the magnet is completely covered. Sprinkle them around if you need to. Now remove the magnet and shake off all the filings not firmly attached to the magnet. Make a record of your findings.

(Experiment time)

Interpretation: Now compare how your magnet attracted the iron filings with other experiments. Notice where the filings are thickest on the magnet. In your records, draw a picture of your system showing evidence of interaction.

(Drawing)

Prediction: Now examine a horseshoe magnet. Predict where you think the filings will be thickest when you repeat the experiment.

(Prediction)

Experimentation: Now test your prediction by covering the horseshoe magnet with iron filings. If you predicted wrongly, try to explain why.

(Experiment time)

INVENTION

Concept: The two areas on a magnet where the attraction is greatest are called 'magnetic poles'.

Understanding the concept: Data from your exploration enable you to answer the following questions:

1. What does a magnet do?

2. How do iron filings behave near a magnet?

3. What types of materials will a magnet attract?

4. What do magnetic poles have to do with magnetism?

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DISCOVERY

Interpretation: Draw a model of a bar magnet. Show how many poles it has. What is your evidence for including the number of poles you did on your model? What is your evidence for locating the poles where you did? Design several other shapes for magnets. Indicate where you think the poles would be located.

(Drawings)

Experimentation: You have just built a model of a magnet. The data you gathered from your experiments made that model possible. What good is your model? Before you can answer that, you need more data. When data are needed you already know experiments must be done.

A bar magnet is needed in this experiment. You also need a piece of string about 30 cm. long. Tie the string around the middle of the magnet. Mark each end of the magner with a different color. Experiment with your string and magnet. You should be able to hold one end of the string and the magnet at the other end should remain flat.

You are now ready to begin gathering data. Go out of doors or in the center of a large room such as the gym. Be sure there is no iron or other material magnets attract around you. What evidence do you have that proves you should not be near certain metals? Hold one end of the string about with your fingers so that the magnet is flat. Observe the magnet until it stops swinging. In what directions do the ends of the magnets point? Repeat the experiment in at least five different locations. Record all of your data. Compare your data with other experiments.

(Experiment time)

Model building: The end of the magnet which points north is called the 'north pole'. The end of the magnet which points south is called the 'south pole'.

Interpretation: Use data your experiment produced. Write a paragraph explaining what those names mean. The poles of a magnet are often called 'north-seeking' and 'south-seeking' poles. Your data tell you why.

(Paragraph)

Experimentation: For this experiment you will need two magnets. Bar magnets or horeshoe magnets will do. Hold a magnet in each hand and slowly bring their ends together. What do you observe? Make a record of your observation. Now reverse one of the magnets. Again bring the ends together. What do you observe? Make a record of that observation also. Based upon what you have observed so far, how do the poles of magnets interact? Make a record of this model of interaction you have built. You will need it for the next experiment.

(Experiment time)

Model building: You have found that some combinations of poles together will produce attraction between the magnets and some will produce repulsion.

Experimentation: Is there a pattern that will explain the attraction and repulsion? To find out you will need to mark both magnets with north and south poles. How is this done? Check your notes if you are not clear. Now experiment bringing the poles of two magnets near each other and make a record of each combination you try. Do this as many times as you need to until you have found a relationship.

(Experiment time)

Model building: You have found that when like poles are brought near each other they repel and when unlike poles are brought near each other they attract.

Interpretation: Write a paragraph about how you would proceed to determine the poles on a magnet if you have another magnet with the poles marked on it. For this excercise you should not consider going back outside as you did previously. You should use the magnet with the poles already determined to find the poles on the 'unknown' magnet.

(Paragraph)

Observation: To help label magnetic poles, you tied a magnet to a string. The same end of the magnet always pointed approximately north. Now get a compass. Go outside or stand a long way from metal. Hold the compass flat in your hand. Notice which way it points. Turn the compass around but keep it flat. Observe what happens.

(Observation)

Interpetation: You have gathered data about the compass. Using all these data, decide what you believe a compass needle is. Record your decision.

(Paragraph)

Experimentation: Now do an experiment to test your decision. The model you made about how magnetic poles interact will help you.

(Experiment time)

EXPLORATION

Experimentation: The experiments you have done so far allowed you to build models about magnets. When you pushed the poles of magnets together you felt something. You felt the magnets attract or repel each other. What caused that attraction and repulsion? Where is this mysterious 'something'? What does it look like? Here again you need data to answer these questions.

To begin with you will need a bar magnet. Lay the magnet in the middle of a large piece of paper. Cover the magnet with a second piece of paper. Now sprinkle just a few iron filings in the space near the poles of the magnet. Observe what happens. Why should you have expected what you say?

(Experiment time)

Now sprinkle iron filings in all directions from each pole. Continue to sprinkle iron filings near the magnet until you can clearly see what is happening. Next start at one pole and sprinkle filings out from it. Keep sprinkling filings out from each pole in all directions. Continue sprinkling filings until the magnet has no affect on them.

(Experiment time)

Interpretation: Compare the size of the area in which the magnet affects iron filings to the size of the magnet. Which is larger? Record how the magnet and the area compare. Draw a line around the area where iron filings are affected.

(Paragraph & Drawing)

Experimentation: Now repeat the experiment using a horseshoe magnet. Make comparisons between what you saw with the bar and horseshoe magnets. Be sure to find out how far away from the magnet it affects iron filings. Draw a line around how far from the magnet iron filings are affected.

(Experiment time)

Place the bar magnet in the middle of the piece of paper. Gather some paper clips, thumb tacks and other objects magnets attract. Find out how close these objects must be pushed toward the magnet before it attracts them. Figure out a way to measure 'close'. Compare your results with other experimenters. Now do the same thing with a horseshoe magnet. What difference in measuring the closeness of objects to the magnet does the magnet's shape make?

Interpretation: Compare the size of the iron filings to other objects. What difference do you suppose the size of the objects makes?

(Paragraph)

INVENTION

Concept: The space around a magnet in which other objects are attracted to it is called a 'magnetic field'. Because magnetic fields can make objects move they contain 'energy'.

Understanding the concept: Data from your exploration enable you to answer the following.

1. What is a magnetic field?

2. How close must objects be to a magnet before being attracted to it?

3. How do iron objects of different size behave in a magnetic field?

DISCOVERY

Interpretation: What shape is the magnetic field of your bar magnet? What is the largest part. How large is it? What shape is the magnetic field of your horseshoe magnet? What is the difference between the magnetic fields of a bar magnet and a horseshoe magnet?

(Paragraph)

Experimentation: Your experiments have shown you several magnetic fields. But you haven't studied a detailed model of one. You have already experimented with an object which will help you. That object is a compass. You know a compass is a magnet. Be sure you know which end of the compass needle is the north-seeking end. In addition to the compass, you need a bar magnet. Hold the compass needle near first one end of the magnet and then the other. What happens to the compass needle when switching ends of the magnet?

(Experiment time)

What happens to the compass needle between the ends of the magnet? You don't know the answer to that question. What has to happen is the compass must be moved through a magnetic field. So the proper way to ask the question is what happens to a compass as it moves through a magnetic field?

You need a large piece of paper. A bar magnet and a compass are also needed. Place the magnet in the center of the paper. Draw lines around the magnet to mark its place. Also mark on the paper where the 'N' and 'S' poles of the magnet are. Those markings may save you a lot of time. If the magnet is moved you know exactly how to replace it. You won't have to start over.

Begin by holding the compass against one of the poles of the magnet. Draw a short line to show the position of the compass needle. Be sure to mark the position of the north-seeking end. Use an arrow. Now place the compass against the other pole. Again mark the position of the north seeking end of the compass needle. Move the compass around the magnet. Place it in at least 20 different places. Always use an arrow to indicate the direction of the compass needle's north seeking end.

(Experiment time)

Model building: A compass always gives you a direction. What you have done is to plot or 'map' the field around a magnet.

Interpretation: Using your data write a paragraph about the directions a compass gives within a magnetic field.

(Paragraph)

Observation: You know that the needle on a compass is a magnet. To review, do this exercise. Get a piece of iron. A nail will do. Hold the iron object close to the compass. Notice how the compass needle is attracted to the iron. Observe how the end of the compass held closest to the iron is attracted to it. You can make first one end of the compass and then the other be attracted to the nail. Data from your experiments have told you that magnets attract unmagnetized iron.

Experimentation: Now take the unmagnetized nail and stroke it in one direction with the north pole of a strong bar magnet. Test the nail now with a compass. Record your observations and try to explain why this happened.

(Experiment time)

Model building: You are able to magnetize a piece of iron by stroking it with a permanent magnet. Your new magnet has a south pole and a north pole as does any other magnet.

Experimentation: Cut your magnetized nail in half using a pair of strong wire cutters. Now test each half of the nail with a compass. Make a drawing of the magnetic field using arrows.

(Experiment time)

Model building: When a magnet is cut in half each piece acts like a magnet in itself exhibiting both north and south poles.

Interpretation: Recall that with electricity it is possible to put a positive charge on an object or a negative charge on an object. Using all the information you have collected so far, do you think it is possible to have a magnet with only a north pole or a south pole? Write a paragraph explaining why you think as you do.

(Paragraph)

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EXPLORATION

You may have wondered if electricity and magnetism are related. You have found some of the properties of electricity and magnetism seem to correspond. For example like charges in electricity and like poles in magnetism repel. Similarly, unlike charges in electricity and unlike poles in magnetism attract. You have also found some differences between electricity and magnetism. For example it is possible to have an object electrically charged with one type of electricity, but it is not possible to have a magnet with only one pole.

Experimentation: In this first experiment a lot of current is required. From your study of electricity you know how to produce a lot of current with several dry cells. If you are not clear, go back and check your notes. Set up a series circuit using two dry cells and a single light bulb. Be sure to test the circuit to see that it is functional.

You have also found that a compass will indicate the direction of a magnetic field. You can use a compass to test for evidence of a magnetic field. Now arrange your wire so that you have a long vertical section about one meter. Run the vertical section through a piece of cardboard and support it on a ring stand. Now turn on the circuit and use a compass to test for the presence of interaction. What do you find?

(Experiment time)

Interpretation: Use your data from the previous experiment to describe what you think the magnetic field around a horizontal section of wire looks like.

(Paragraph)

Experimentation: Use the compass to plot the magnetic field around the wire. Make a drawing of your apparatus and indicate the direction the compass points. Use an arrow to indicate the N pole of the compass. Also indicate the direction of the current flowing in the wire.

(Experiment time)

Prediction: Predict what you think will happen to the magnetic field when the current is reversed in the electrical system.

(Prediction)

Experimentation: Now test your prediction by reversing the current and plot the magnetic field using a compass.

(Experiment time)

Prediction: Are there other forces other than the current which may affect the compass reading? Predict what you think will happen as you change the number of dry cells in the circuit. Predict both for adding and reducing the number of dry cells.

(Prediction)

Experimentation: Now test your prediction by performing the experiment.

(Experiment time)

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INVENTION

Concept: Current flowing through a wire will produce a magnetic field around the wire. This phenomenon is known as 'electromagnetism'.

Understanding the concept: Data from your exploration enable you to answer the following.

1. What can you say about the magnetic field when no current is flowing in a wire?

2. What produces a magnetic field around a wire?

3. What is the shape of the magnetic field around a current carrying wire?

4. How are electricity and magnetism related?

5. What does the direction of the current have to do with the magnetic field?

6. How does changing the amount of current in the wire change the magnetic field?

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DISCOVERY

Interpretation: The direction of a magnetic field depends on the direction of the flow of current in the wire. There is a convenient way to remember the relationship of a magnetic field to the current in a wire. It is called the 'left hand rule' and it works like this. Point your left thumb in the direction of the current flow along the wire (toward the '+' pole of the dry cell). Then curl your fingers around the wire. They will always point in the direction of the arrows you have drawn. That is they will point toward the north-seeking point of the compass. Go back to your data and try out the left hand rule to see how it works.

Prediction: So far you have been working with a straight piece of wire. You now will change your apparatus somewhat by making the wire into a loop. You wire loop should be about 10 cm. in diameter. Before you experiment predict what you think the magnetic field will be at several places around the loop. Make a drawing and a record of your prediction.

(Prediction)

Experimentation: You are now ready to test your prediction. Use a compass to determine the magnetic field around a loop of current carrying wire.

(Experiment time)

Model building: All the sections of wire in a loop produce magnetic fields in the same direction. The field in the center of the wire is stronger than one produced by the same current in a straight wire because the loop combines the affect of the entire section of wire.

Prediction: What do you think will happen when you make a system with several loops?

(Prediction)

Experimentation: Test your prediction by making a system with several loops.

(Experiment time)

Now add a large nail to your system. Wind many loops of wire around the nail. Where will the compass indicate the north-seeking magnetic field is? What is the purpose of the nail?

(Experiment time)

Model building: You have constructed an 'electromagnet'. An electromagnet used the flow of electricity in a wire to produce a magnetic field.

Experimentation: Test the magnetic field at several points around your electromagnet with a compass. Make a plot of these in your records.

(Experiment time)

Model building: An electromagnet has poles and in many respects resembles a bar magnet.

Interpretation: There are many uses for electromagnets. These uses depend upon three characteristics of electromagnets you have discovered.

1. Electromagnets can be made extremely powerful.

2. The magnetism of an electromagnet can be turned on and off.

3. The direction of magnetism can be reversed in an electromagnet.

EXPLORATION

Observation: You will now investigate some of the uses of electromagnets. Begin by closely examining a telegraph. Make a drawing and label each of the parts.

(Drawing)

Experimentation: Now make a system using the telegraph, a telegraph key (switch) and a dry cell to produce interaction.

(Experiment time)

This idea can be expanded to another simple device, an ordinary door buzzer. Examine one closely and make a sketch of the important parts. Make a system of a door buzzer, dry cell and a switch to produce interaction. Why does the clapper vibrate as it does? What is the purpose of the 'contact points'?

(Experiment time)

Interpretation: Some door bells do not buzz, rather make a series of chimes. How do you think they work? Make a drawing of what you think is inside one of these kinds of door bells.

(Drawing)

Experimentation: Use an electromagnet to pick up as many nails as you can. When you pick up the nails are you doing any work? Is the electromagnet doing anything?

(Experiment time)

INVENTION

Concept: The properties of electromagnetism can be used to convert electrical energy into mechanical energy.

Understanding the concept: Data from your exploration have given you the following information.

1. The electric current in the electromagnet of a telegraph produces energy to move the clapper which makes the clicking sound.

2. A buzzer utilizes an internal switching system to turn the electromagnet on and off very fast. This produces the buzzing sound.

3. An electromagnet produces mechanical energy in picking up nails that is derived from electrical energy.

BACKGROUND INFORMATION

For many years scientists had futilely tried to produce magnetism from electric current. They had also tried to produce electric currents from magnetism but were unable to do so They had been unable to establish a relationship between magnetism and electricity. In the early 1800's no relationship had been discovered. Then in 1819 a Danish scientists named Hans Christian Oersted made a remarkable discovery. He was teaching a class about electricity when he placed a compass next to a current carrying wire as you have done. You already know what happened to the compass. Oersted had tried before to find a magnetic field with a compass but had been unable to do so. When he turned the current off, the compass returned to its original position. He then realized that he had discovered the connection between electricity and magnetism.

DISCOVERY

Observation: There is another way to convert electrical energy into mechanical energy. Look at the drawing below. In the center is a magnet that is free to rotate. This is a pivotal magnet. On each side of the pivotal magnet is a stationary bar magnet. Now make another drawing to show what you think will happen when the pivotal magnet is allowed to rotate.

Interpretation: The pivotal magnet only makes less than one-half of a revolution (less than 180°). Think of a way to make the magnet revolve continually. Write down how you think this could be done.

(Paragraph)

Model building: The magnet that is free to rotate would do so continually if the poles could be changed every 180°: i.e., every half revolution. The poles of a permanent magnet cannot be reversed. However, the poles of an electromagnet can be reversed. You already know that to do this all you need do is change the direction of the current.

Experimentaion: You are going to make a device that will utilized the information you have discovered. First make a pivotal electromagnet. To make the core saw two 16-penny nails to a length of about 5 cm. Wrap the insulated copper wire around the nails. Now start winding at the middle of the nails, leaving 40 cm. of unused wire at the end as you begin to wind. Wind from the center of the nails all the way down to one end but do not wind so close to the end that the wire slips off. Wind back all the way to the other end, then back to the middle. When you finish, cut the wire to allow 40 cm. of free wire at this end also.

Now make the pivot for the electromagnet. Drive a long nail into the center of a wooden base. Then sharpen the end of the nail. Now seal a piece of glass tubing at one end so that it is smooth and concave. When the tubing is cool, cut it to a length of about 10 cm. and insert it through a large one-hole rubber stopper. Place the glass tubing over the sharpened nail. Fasten the electromagnet securely to the top of the rubber stopper with rubber bands or tape. The pivotal electromagnet is called an 'armature'.

Next mount the two bar magnets so that one N pole and one S pole will be next to the armature. These non-moving magnets are called 'field poles'.

You are now ready to begin experimenting. Connect the wires from the armature to a cell or a battery of two or three cells. If you have constructed your equipment carefully you should observe interaction. Make a record of it.

(Experiment time)

Now reverse the current in the electromagnet and observe what happens. Do this several times.

(Experiment time)

Interpretation: Does the armature turn in any particular direction? Can it turn equally well in either direction? Does this agree with what you know about the behavior of like and unlike magnetic poles?

(paragraph)

Prediction: What will happen to the motion of the armature if one field magnet is removed? What will happen if one of the field magnets is reversed?

(Prediction)

Experimentation: Test your predictions by experimenting.

(Experiment time)

Model building: The armature will rotate continuously if you keep reversing the current every half revolution. This would be a problem if you were to do this by hand. Some electric motors turn as high as 20,000 times a minute. To accomplish this you need a special kind of switch. It will need to operate very rapidly and change at whatever speed the motor is turning. It also must be made so that the wires will not wind up on the armature.

Experimentation: To make this kind of switch peel the insulation off of the two wires coming from the armature for about two centimeters. Then tape them to the glass tubing so that they are directly below the electromagnet. Now bare the ends of two other pieces of wire by 2 cm. also and bend them in an arc to fit around the glass tubing. Mount them on the board and bring the bare ends in contact with the glass tubing so that the armature wires will brush against them.

Now examine what you have built. How does this arrangement satisfy the requirements previously mentioned? How often is the current reversed? How fast can the current be reversed in the armature? Does the armature rotate everytime the current reverses? Will the wires get twisted as the armature rotates? The device you have built that reverses the current is called a 'commutator'. The wires that are arced around the glass tubing are known as 'brushes'.

Model building: The device you have just built consisting of a pair of field magnets, an armature, a commutator and brushes is known as an 'electric motor'.

Observation: You are now ready to try out your electric motor. Connect the brushes to a dry cell. You may have to give it a start and you may have to make some careful adjustments on your motor before it will work. The commutator brushes and contacts must be clean. You may also have to tighten or loosen the connections a little. Also you may need to adjust the position of the brushes.

Experimentation: You have now constructed a small electric motor that works. It is not big enough to do any useful work but it does illustrate the principle of the electric motor. Your motor and some small motors use permanent magnets to generate the magnetic field. Most larger motors use electromagnets for the field magnets. See if you can modify your motor to use field magnets that are electromagnets.

(Experiment time)

Experimentation: Experiment with a coil of wire in a magnetic field. Try to generate electric current. You will need a galvenometer to detect the current. Experiment with different numbers of turns in the coil. How does the number of turns affect the amount of current produced?

(Experiment time)

Model building: A coil of wire will produce current depending on the number of turns in the coil.

Experimentation: You have been experimenting with a simple electric generator. How can you apply what you have just learned to generate electricity for practical purposes? You know that you must have a wire moving back and forth in a magnetic field to generate electricity. To understand how practical generators work do this experiment.

Place two bar magnets with opposite poles about 5 cm. from each other. Now take the coil of wire you have been using and put it between the two magnets. Experiment to find a way to generate electricity from your system. What happens to the current as you make a full turn of the coil?

(Experiment time)

Model building: The electric current reverses as a full rotation of the coil imade. This type of current is known as 'alternating current'.

Interpretation: The electric current you have used until now supplied by a cell is known as 'direct current'. Write a paragraph showing that you understand the difference between alternating current and direct current.

(Paragraph)

Interpretation: You still have the problem in your generator of getting all the wires twisted as the coil rotates. Devise a system that will solve this problem. Make a drawing of your system. Is this similar to your electric motor?

(Paragraph & Drawing)

Experimentation: Use your electric motor to produce electricity. You will need to use permanent magnets for the field magnets. Does your generator produce direct or alternating current?

(Experiment time)

Observation: You may have wondered how the meters you have been using were able to measure current. Look carefully at how an ammeter is constructed. Do you find any field magnets? Are these electromagnets or permanent magnets? Do you find a coil of wire? Where is it located? Do you find a commutator. If you do not can you give a reason why? How else is a meter different from an electric motor? Make a drawing showing the important parts of the ammeter.

(Observation & Drawing)

Model building: A meter works on basically the same principle as an electric motor. It is different in that the armature is connected to a spring and it has no commutator. The spring acts to prevent the armature from rotating. You already know that the more current there is in the coil the stronger the magnetic field it produces. The meter can be calibrated so that the strength of the magnetic field pulling against the spring can be measure.

Interpretation: Most ammeters would burn out if all the current were allowed to go through the coil. Examine the design of the meter again. Is there another path the current may take? Is it wired in series with the meter or in parallel? Write a paragraph explaining how you think the ammeter works.

(Paragraph)

Model building: Most of the current that goes through the meter does not go through the coil. Rather there is a device known as a 'shunt' wired in parallel with the coil that allows the major part of the current to pass through without going through the coil.

APPENDIX C

SAMPLE LECTURES FOR FORMAL INSTRUCTION

SAMPLE LECTURE * * * FORMAL INSTRUCTION * * * STATIC ELECTRICITY

Electricity is a form of energy. Static electricity occurs when small charged particles called electrons are caused to move onto or off of an object causing an imbalance of the remaining positive charges.

Static electricity is also a form of energy. An object can become electrically charged by adding or removing small charged particles called electrons. All neutral atoms contain the same number of positive charges, protons, and negative charges, electrons. In ordinary static electricity the protons do not move. Only the electrons are mobile. By adding electrons to neutral atoms you will cause the object to acquire a negative charge. Similarly, by removing electrons from neutral atoms, you will cause the object to acquire a positive charge. Let's see how this works.

I have a rubber comb just like the ones you buy in the drugstore. I also have some paper which I will tear into small pieces. Now I will bring the comb close to the paper and you notice that nothing happens. Paper and rubber do not normally interact. I can however, do something to the comb which changes it. I will rub the comb with a piece of wool for a minute or so. Now when I bring the comb next to the paper it picks up the paper. Now the comb and paper are interacting, there is an attraction between them.

I can do the same thing with a glass rod and paper. Glass and paper do not normally attract, but if I rub the glass with a piece of silk, I can pick up the paper as before.

These are two examples of static electricity. Other examples of static electricity are:

1. Rubbing a balloon on a shirt to make it stick to a wall.
2. Lightning.
3. Rubber-soled shoes in which someone has walked over a wool rug.
4. A wool coat which has been rubbed against plastic seat covers.
5. A nylon dress which has been dried in a clothes dryer.

We have learned that static electricity can be produced when two objects are rubbed together. There are two types of charges that objects may acquire, positive and negative.

When two objects that have the same charge are brought near each other, they will repel. This can be shown using two identical balloons. I will first charge each balloon with the same kind of charge by rubbing each one with a wool cloth. Each balloon has a silk string attached to it. Notice when I bring them close to each other they stand out away from each other.

If two objects have different charges they will attract each other. I will first charge a glass rod by rubbing it with silk. Doing this causes electrons to leave the glass and stick on the silk. The glass rod now has a positive charge due to its deficiancy of electrons. I will now suspend the charged glass rod with silk thread so that it is horizontal. Next I will charge a rubber rod by rubbing it with wool. Here the electrons move from the wool to the rubber thus giving the rubber tod a negative charge due to an excess of electrons. Notice when I bring the negatively charged rubber rod near the positively charged glass rod, that they attract each other.

To review: If two objects have the same charge, they repel each other.
If two objects have a different charge, they attract each other.

SAMPLE LECTURE * * * FORMAL INSTRUCTION * * * MAGNETISM

Magnetism is a form of energy also. It is similar to electric energy in some ways and different in other ways. Some of the properties of magnetism and electricity are interrelated and will be studied in the next unit.

You already probably know quite a bit about magnetism. You may have used magnets around your home or played with a toy magnet. You know that magnets will attract certain pieces of metal when they are brought close enough together.

Background information:

The discovery of magnetism seems to have come about by accident. It is not really known exactly how magnetism was discovered. The ancient Greeks wrote about magnets some 2,500 years ago. It is also very probable that the Chinese discovered magnetism about that time also. The story is told that magnetism could have been discoverd like this. A long time ago a shepherd tied a piece of metal to the end of his staff so that it would not wear away as he walked across the hills. One day he noticed that as he placed his staff near a grayish rock he felt a strange pull on the staff. Other legends are also told that may or may not be true. You might want to look in an encyclopedia to find out about some of them.

The origin of the name 'magnet' is also unclear. The legend exists that the first magnets were found in an area of Greece known as Magnesia or Magnetes. Other reports say the name of the first man to find magnetism was Magnes. Magnets were also called 'lodestones'. The word 'lode' is an old English word meaning "course".

Magnets will attract only certain types of materials. A magnet will not attract anything that is not metal. Wood, paper, glass and plastic are some common examples of things magnets will not attract. Some metals such as iron, nickel and cobalt will be attracted by magnets. Other metals such as aluminum and copper will not be attracted by magnets.

Using a bar magnet and some iron filings the areas on a bar magnet that are the strongest can easily be seen. Notice that most of the filings congregate at each end with very few in the middle. The areas on the magnets where the filings collect are called 'magnetic poles'.

A horseshoe magnet is similar to a bar magnet but it has been bent so that the poles are close together. Again iron filings will congregate at the poles where the magnet is the strongest.

The poles of a magnet are named North and South. If a magnet is allowed to freely find its rest position, the North pole will point toward the north pole of the earth and the South pole will point toward the south pole of the earth. More precisely the name of the North pole of a magnet is the North-seeking pole, and the South pole is the South-seeking pole. As you would expect a horseshoe magnet has a North and South pole also.

Magnets do not always attract metal objects. They will attract a piece of iron if the second piece has not been magnetized. Two magnets behave quite differently however. When the North poles on two magnets are brought near each other they will repel. Similarly, when the South poles on two magnets are brought near each other they will repel. If a North pole of one magnet is placed in the vicinity of the South pole of a second magnet, the two will attract each other. This behavior is similar to electrical charges where two like charges repel and two unlike charges attract.

A compass is simply an instrument that contains a small magnet suspended in the center by a sharp point so that it is free to rotate. The outside of the compass is made of non-magnetic materials, usually aluminum and glass or plastic. Since the compass is a small magnet is has a north and south pole. A compass is used for navigation purposes. It is not exactly accurate however. The compass will always point to the magnetic north and not the geographic north. The difference between true north and magnetic north is called declination. Scientists have measured the difference between magnetic north and true north at all points of the globe. From these data it is possible to draw a map showing the declination at any spot on earth. In order to be used for navigation you must correct a compass reading for the declination in your location.

SAMPLE LECTURE * * * FORMAL INSTRUCTION * * * ELECTROMAGNETISM

Electricity and magnetism are related forms of energy. You have found some of the properties of electricity and magnetism correspond. For example like charges in electricity and like poles in magnetism repel. Similarly unlike charges in electricity and unlike poles in magnetism attract. There are also some differences you have learned about electricity and magnetism. For example it is possible to have an object electrically charged with one type of electricity, but it is not possible to have a magnet with only one pole. You have also learned that a magnet has a field around it. It turns out that an electric current also has a field surrounding it.

For many years scientists had tried to produce magnetism from electric current. They had also tried to produce electric currents from magnetism but were unable to do so. They had been unable to establish a relationship between magnetism and electricity. In the early 1800's, no relationship had been discovered. Then in 1819, a Danish scientist named Hans Christian Oersted made a remarkable discovery.

Hans Oersted was teaching a class about electricity. He was showing them some of the things about wet cells that you have already learned. Remember that up until this time scientists thought that electricity and magnetism were not related. Oersted placed a magnetic compass near a wire to prove his point. He had done this many times before, but this time he noticed the compass move when the current was started. When he turned the current off the compass returned to its original position. He then realized that he had discovered the connection between electricity and magnetism.

An electric current flowing through a wire will set up a magnetic field around it. This magnetic field is different from the field around a bar magnet in that it does not exhibit any poles, rather it is circular. If you place a compass at strategic places around the wire you will find that the compass will point north on one side and point the other direction on the other side. As you continue to go around the wire the compass will turn and make one revolution for every one you make with the compass. Notice that this magnetic field is perpendicular to the flow of electricity. The reason Oersted's first experiments were unsuccessful is that perhaps he had the compass in a position that was not perpendicular to the current.

As you might expect when the current in the wire is reversed, the magnetic field will be the opposite. You can use a simple procedure to determine the magnetic field. This is called the 'left hand rule'. If you point your thumb of your left hand in the direction of the current and curve your fingers around the wire, they will always point in the direction of the north position of a compass. Remember this field is circular so it will be opposite on the other side of the wire.

It is possible to magnify the magnetic affect of a wire by making it into a loop. If you apply the left hand rule to different positions around the loop you can see that the direction of the magnetic field inside the loop is always the same. In other words you can concentrate the magnetic field along a stretch of wire in one place by looping it. You can increase the magnetic field even more by making several loops together.

An electromagnet is a coil of many turns of wire usually wound around a piece of iron or steel. Because the coil is wound around the length of the metal, the metal takes on the properties of a bar magnet. The final effect is to produce lines of force that come from one end of the coil, travel around the outside, and come back to the other end just as a bar magnet.

There are many uses for electromagnets. These uses depend upon three characteristics of electromanets:

1. Electromagnets can be made extremely powerful.
2. The magnetism of an electromagnets can be turned on and off.
3. The direction of magnetism can be reversed in an electromagnet.

A simple practical device that uses an electromagnet is a telegraph. A telegraph is made by constructing an electromagnet and then placing a clapper at one end of the magnet. When the current is turned on, the magnet will attract the metal clapper and make a sound. The current can be controlled by a telegraph key (switch) to make a series of sound in code.

Another simple practical device is an ordinary buzzer or bell. The clapper is made to vibrate using an internal switch or set of contacts that break when the clapper is attracted by the electromagnet. It then returns due to a spring and reestablishes contact and the cycle is repeated again.

APPENDIX D

ATTITUDE QUESTIONNAIRE

AND

SPECIFIC RESPONSES

DO NOT PUT YOUR NAME ON THIS QUESTIONNAIRE.

PHYSICAL SCIENCE * * * STUDENT EVALUATION OF COURSE
NOBLE HIGH SCHOOL * * * MR. SCHNEIDER

Answer the following questions as honestly as you can. Do not discuss the questions with another student. Your responses to these questions will in no way affect your grade in this course.

1-3. How would you classify the primary teaching procedures used in this course? (Check as many as applicable, but if you check more than one, please rank your selections 1, 2, 3, etc. in order from most frequently used to least frequently used).

_____Lecture
_____Small group discussion
_____Large group discussion
_____Laboratory group work
_____Lecture-demonstration
_____Teacher demonstration without extensive lecture
_____Materials (apparatus) centered teaching
_____Working alone in the laboratory
_____Instructor working sample problems
_____Instructor working with individuals and small groups
_____Instructor telling the students what content they should learn
_____Instructor assisting the students in learning the content

4. Which of the following describes the general feeling you have about how this course has been conducted? (Most probably there will be exceptions to whichever response you select, but select the one which describes your overall feeling.) Encircle your choice.

(a) I felt I was being told what content material to know.
(b) I felt I was being led to find out about the content material.

5. Evaluate your own feelings about the teaching procedures used in this course. Check as many of these as are applicable to you.

_____I liked them.
_____I did not like them.
_____I liked them, but felt insecure for a few weeks.
_____I did not like them, because I felt insecure.
_____I liked them, but felt insecure for the entire semester.
_____I liked being told what to do.
_____I liked finding out ideas for myself.

PHYSICAL SCIENCE * * * STUDENT EVALUATION * * * PAGE TWO

6. Write a few lines which describe your feelings about the physical science course you just completed.

7. How much did your instructor add or detract to your feelings about the course?

8. What changes would you like to have been made that you think would improve the course?

9. Please complete one of the following statements as concisely as possible.

   (a) I prefer a standard lecture course because________________________

   ____

   ____

   ____

   (b) I prefer a course based on laboratory experience because__________

   ____

   ____

   ____

10. Compare this course in physical science to other <u>science</u> courses you have taken. (Circle one)

   (a) I learned very much less content material than in my other science courses.
   (b) I learned less content material than in my other science courses.
   (c) I learned about the same amount of content material as in my other science courses.
   (d) I learned more content material than in my other science courses.
   (e) I learned very much more content material than in my other science courses.

11. Compare this course in physical science to other non-science courses you have taken. (Circle one).

    (a) I learned very much less content material than in my other non-science courses.
    (b) I learned less content material than in my other non-science courses.
    (c) I learned about the same amount of content material as in my other non-science courses.
    (d) I learned more content material than in my other non-science courses.
    (e) I learned very much more content material than in my other non-science courses.

Specific responses for item six of the attitude questionnaire.

Concrete Instruction Group

Science is hard to understand.
It was OK but hard because science is hard to understand at least for me.
I didn't like the stuff we talked about. I want to do experiment with chemicals and have you as a teacher, not (name of another ninth grade science teacher in the school system).
It was very interesting & enjoyable but still it taught me a lot.
I liked the teacher and I liked the course. I just wished I had the same on 2nd semester.
Its OK.
I think that everyone should take a course like this so they will learn how gerators work.
I liked to do most of the experiments and finding out about things.
It was OK but I hate science.
It was fun sometime and sometime I did not like it.
I don't care that much for science but if it is explained it is okay.
It was easy if you did your work and listen.
I liked this course, but sometimes I didn't understand the experiments. I liked it when you did the experiment and told us what to write down. I learn better that way.
It was OK except I did not like at all the sheets we did every day.
It was fun done the experiments the way we wanted to.
I liked it alot doing this.
I understood it better than I have ever understood science before. I wish there were more teachers like you.
I liked it because it was fun and interested in it.
I don't really have any feelings about it. I neither like or dislike them.
Some of it was fun and some wasn't. So(me) of the time it was boring and some of the time it wasn't.
I liked it but once in a while I felt lost but I know it's my own fault for not paying attention.
It was a lot of fun. But I don't care that much about working with electricity.
It has been the best science class I have had since I've been to Noble.
Some ways I like, it was fun, but some of the students didn't know self discipline.
Well I like it. It seemed like I learned a lot. It was kindly fun.

Formal Instruction Group

It was really nice part of the time. It got hard but you helped a lot.
I didn't seem to really care about it. Like I wasn't interested. It was boring and I usually liked it.

I felt I didn't need the course but I enjoyed parts of it anyway.
It wasn't very interesting mostly because everyone went rule and they made me very nervous and irrated.
It was OK but I never really understand science.
I didn't understand it that well at first.
I liked it & the teacher but classmates hindered some people who wanted to learn from doing so.
I don't like it.
I hate it.
I think it could have been better with <u>more</u> lab work.
I didn't like it because it was boring.
It was a fun class.
I don't like physical science at all, but the kids & the teacher are allright.
It was okay and, most of the time but some were boring. Your a great teacher its just that some of us don't listen.
I think I just didn't understand it very much but I learned quite alot.
I liked it, and I wish I had more of it to do.
I liked it because it wasn't strickly by the book.
I didn't like it cause it wasn't interesting and it was hard to understand.
It taught me a few things I didn't know & it interested me because I like electronics.
It s(h)owed me alout of new stuff.
I feel the teacher didn't teach us what we would have liked to hear.
It was interesting and the things we learned were well explaned.

Specific responses for item seven of the attitude questionnaire:

<u>Concrete Instruction Group</u>

He was a big enfluence.
He helped a lot.
He made it interesting, made me want to find out what it was all about.
He added a lot because he always tried to help me solve my problems in class.
None (four responses)
He added a lot because he helped us.
A little because the way you would help individually.
I like the instructor a lot, but you need to explain in words easier to understand.
He acted like he really cared.
He added a lot by being the teacher he is. He was comb and explained.
He made me learn things.
No change.
I liked it better than last year.
He made it bitter.

He really made me want to find things out more. He made it more enjoyable.
You get involved, you cared about which wanted to make us work.
If I didn't understand it he would explain it to me.
Well I like it more now.

Formal Instruction Group

He added to my feeling because last year I made a C and this year an A.
Nothing.
He helped me alout with it.
You had your good points and you bad points on a scale from 1-10 I'd give you an 8.
Added
You made it more exciting.
He added a lot, and I think I could work better if I had him teaching me all of the time.
I think you used words out of my reach.
He added because he helped us find out answers.
Quite a bit.
A lot
He didn't
Not vyry much
As much as he should.
He helped us like any other teacher & a whole lot more. I liked it.
He tryed to help me understand about what we are doing.
He made some of it entersting. Like the one about the colors.
My feelings have neither increased or decreased just remand the same.
He dectracted it quite a bit.
The teacher really trys hard but some people just made it harder to understnad.

Specific responses for item eight of the attitude questionnaire:

Concrete Instruction Group:

More demonstration and explaining.
Do experiments with chemicals.
None (4 responses)
I can't really think of any. (2 responses)
Not to do any work.
No changes.
Stricter teacher.
No papers to fill out.
If there were more more words that were explained a little better.
No so many papers in one day. (2 responses)
I don't know.
He would not answer my questions fully.

More experiments.
More experiments on different subjects.
Myself, I need a little more personal attention, but I really didn't ask.
To have done chemistry experiments.
To have it for two semesters.
A less routy class.

<u>Formal Instruction Group</u>:

Slow down.
More lab work and group discussion, also the teacher help explain.
Change the course from 'routine' to something else.
No lectures or not very many. I myself can't learn by writing notes as fast as I can and then try to read what I write.
Let us do some of the experiments.
That everybody wouldn't talk all the time.
Assigned seats, because the class was segragated.
Him explan things to us.
Different course.
Telling why you answers on the test could be left out.
<u>Cut the Notes</u>!!!
Experiments for us.
Not so many work sheets.
That the people in the back would keep their mouths closed and shut up once in while.
Not take so many notes nor demonstration.
None, it's fine like it is, and I think if it is changed it would be worse than it is now.
<u>No notes</u> and let the kids be able to do some experment.
Drink cokes in class.
Not just doing the same thing every day.
To let the kids do the experments and maybe the(y) would learn something, insted of taking 3 pgs. of notes every day.
More information to study off of such as study sheets.

Specific responses for item nine of the attitude questionnaire:

<u>Concrete Instruction Group</u>

I prefer a standard lecture course because:
lecture makes it easier to understand.
a lecture explanes it bitter.
they help you more.
you can take notes on things you don't know and not wright down the things you do.

I prefer a course based on laboratory experience because:
- it is more fun to do and to discover new things.
- it's more interesting and I think you get more out of it.
- it gets people more interested in the work, and maked them want to figure it all out.
- you do them yourself. And I feel you learn more by doing them and do lab. work yourself. Helps you a lot.
- I feel there is more to do and learn.
- you learn more from it because your'e doing it.
- I like experiments & teachers teand to gripe on lectures.
- it teaches me more about science.
- it is easier to rember what you did, you seen it for yourself, you can talk while your are doing your experiment.
- you see the experiments and just not listen to them.
- I learn better by experience, but I wasn't sure what you wanted me to learn.
- they are a lot more interesting and they are fun and give you something to do.
- it is more interesting to me and most people that can't understand lecture.
- it better to find out by your self than to let someone teach you.
- you can learn more for yourself with laboratory.
- you can learn more when you do it yourself.
- its a lot more fun to work things out with you friends and find things out for yourself. You get bored listening to people tale on and on.
- you can experience what you are doing and learn a lot more.
- it is more fun. Not so boring.
- I don't like to listen to alot of talikng that I already know about.

<u>Formal Instruction Group</u>

I prefer a standard lecture course because:
- you can understand it and refer back and look at diagrams.
- I'm not very good in labrotory because I don't understand it very well and I will probably fail in it. It's fun (lecture).
- I like to have a lecture course and do a lot of stuff. I think it's fun.
- I can learn beter when told to me.

I prefer a course based on laboratory experience because;
- you learn and arn't told.
- you get to do experaments and you learn more when you do experiments.
- you can learn and also understand and see what you are learning.
- I think it helps the kids find out more.
- I like to do things on my own.
- I like to do experiments my self.
- its fun and you always learn from experince.
- when I see what realy is going on I rember it more, and enjoy it.
- people seem to remember more about something if there's laboratory experience.

you can learn more with doing it yourself.
you learn more & remember it if you see it yourself.
you work with other people and learn about them as you learn about the experiments.
I like to do some kinds of laboratory. I hate lectures.
it would be funner.
it helps to know all the facts and be able to prove for yourself that it works or it doesn't work or that a theory is right or wring.
you get to do something different every day.
we can know the true facta dna understand them better. We wouldn't be so bored.
you can really see it happening instead of just talking about it.

The following comments are unsolicited responses made by students in the formal instruction group on the back of the attitude questionnaire.

I learn what I feel like learning. I don't like school too much, much less science. This years science was much different than last years because it wasn't boring. Since we have to have two years of science I hope I have you next year because I liked having you for a teacher. I like the way you grade.
I neither liked, disliked or felt insecure about this class. It just was very hard for me to learn through lecture style teaching because you talk in circles and I don't understand your lectures and trying to get all the notes is very difficult for me because I don't learn anything. I like to experiment and try.
I don't think there is a science teacher at Noble that cares what they teach. They teach to see how much they can teach but not how much the kids learn. If a teacher doesn't teach the kids anything they haven't taught.
Mr. Schneider, I think you are the best teacher there is, and I wish you would stay for the next semester. I wouldn't mind having you for a teacher all of the time. Stay the way you are. Friends always, me.
Mr. Schneider, you are probably one of the best science teachers that I've have. I hope I can have you in the future to come. I wish you weren't leaving cause you're a cool person. Have fun wherever you go.
Mr. Schneider, you were a great teacher and <u>really</u> far-out. I hope I can have you again some year. It was fun in here, Make sure I don't get in a class with alot of big mouths like (names of two girls).

APPENDIX E

CONTENT EXAMINATION RELIABILITY

TABLE E-1

RAW DATA FOR RELIABILITY OF CONTENT EXAMINATIONS
MULTIPLE CHOICE

Student	S. E.		C. E.		L & O		Sound		Mag.		E. M.	
Number	Odd	Even	Odd	Even	Odd	Even	Odd	Even	Odd	Even	Odd	Even
1	13	10	20	30	20	15	10	13	10	30	0	10
2	10	30	20	30	20	30	20	8	20	20	20	20
3	43	13	30	10	20	20	20	13	20	25	13	40
4	0	20	35	20	0	20	20	23	10	20	5	20
5	10	15	30	25	10	10	10	20	15	30	30	0
6	18	10	20	0	20	10	0	20	20	10	25	0
7	6	25	25	20	20	20	10	15	20	0	0	20
8	18	10	25	25	10	10	20	10	20	20	0	10
9	23	25	30	30	30	30	40	20	5	20	20	20
10	*	*	25	30	10	30	20	13	20	20	15	20
11	15	20	30	15	30	0	15	23	30	15	11	20
12	23	20	30	30	10	5	20	10	10	30	10	0
13	0	10	20	30	20	30	25	23	0	20	20	10
14	18	33	30	20	30	40	20	20	30	30	16	30
15	3	30	17	40	35	25	15	3	20	10	30	10
16	28	0	30	20	10	10	10	13	10	15	0	10
17	20	20	20	40	30	10	30	10	25	10	10	25
18	21	35	30	15	10	5	20	13	20	10	*	*
19	*	*	40	30	30	20	20	20	20	15	18	15
20	30	5	30	20	0	5	15	5	0	10	10	10
21	23	25	25	35	20	20	10	21	20	20	13	20
22	0	0	25	30	10	25	25	20	10	15	30	15
23	10	5	0	7	10	20	10	10	0	0	35	10
24	*	*	*	*	10	25	20	10	10	30	30	20
25	15	28	30	10	0	0	20	10	10	20	30	10
26	10	23	*	*	0	0	40	20	0	10	*	*
27	*	*	0	17	10	30	10	10	10	10	0	0
28	40	20	5	15	0	0	20	13	10	20	20	0
29	31	28	10	0	30	5	10	23	10	25	20	10
30	10	20	10	20	20	5	15	3	30	20	10	0
31	13	10	0	0	0	0	20	10	0	30	10	5
32	16	30	30	25	25	15	18	15	20	10	30	20
33	33	10	30	0	20	5	5	23	10	20	10	0
34	3	5	0	0	0	0	0	20	0	0	0	0
35	37	18	0	10	10	0	30	20	0	10	0	0
36	18	10	0	0	0	5	5	0	10	20	0	0
37	20	20	0	10	35	20	15	20	10	20	20	30
38	10	10	15	0	10	10	10	3	15	10	10	5
39	20	20	0	0	20	10	0	23	0	10	0	0
40	18	20	30	0	10	0	10	20	10	10	40	10
41	23	15	5	5	0	10	25	3	15	10	25	0
42	25	23	17	0	10	10	25	15	10	25	10	20
43	23	0	5	17	13	20	30	13	0	0	10	10
44	8	23	22	0	15	15	15	20	20	25	0	5
45	40	20	20	8	20	15	30	20	30	30	20	5
46	35	25	5	10	10	25	30	23	10	10	20	0
47	10	18	0	10	10	15	20	20	0	10	0	0
48	*	*	*	*	0	0	0	0	0	0	10	10

*Indicates that the student was absent on the day of the examination.
Students No. 1-23 experienced concrete instruction.
Students No. 24-48 experienced formal instruction.

TABLE E-2

RAW DATA FOR RELIABILITY OF CONTENT EXAMINATIONS
FREE RESPONSE

Student	S. E.		C. E.		L & O		Sound		Mag.		E. M.	
Number	Odd	Even	Odd	Even	Odd	Even	Odd	Even	Odd	Even	Odd	Even
1	20	22	32	9	26	10	25	25	25	8	24	0
2	30	2	15	15	21	8	22	15	35	28	10	0
3	40	28	12	17	10	10	4	12	33	26	37	10
4	35	5	22	15	17	0	19	20	17	8	15	10
5	30	8	12	19	28	0	0	14	25	8	10	5
6	15	17	17	14	24	0	10	15	33	25	40	0
7	40	30	22	7	19	0	25	25	15	19	19	10
8	40	13	20	17	17	10	0	4	22	22	*	*
9	35	19	32	25	33	25	27	27	30	28	34	5
10	30	21	22	14	27	8	20	23	33	20	14	10
11	30	20	15	12	14	19	25	25	38	23	30	27
12	30	12	11	24	22	10	30	12	20	13	20	0
13	50	14	32	15	26	5	15	21	27	8	14	5
14	60	28	33	14	25	25	24	25	40	16	24	15
15	50	19	22	10	25	8	25	20	15	15	10	5
16	20	17	17	9	13	0	19	19	20	20	7	0
17	50	15	12	27	27	30	20	20	21	21	14	5
18	50	33	15	15	31	6	0	22	25	20	17	10
19	0	21	29	20	14	5	10	17	33	20	32	0
20	40	11	18	10	17	5	15	7	10	15	14	0
21	30	14	*	*	30	0	20	17	40	28	29	0
22	0	8	22	4	20	5	20	10	25	8	20	30
23	25	8	0	0	9	0	0	0	10	8	14	0
24	35	28	*	*	13	26	30	20	28	30	20	0
25	40	16	12	12	15	5	20	17	28	13	17	0
26	0	24	*	*	10	15	0	10	35	15	*	*
27	0	1	12	6	8	10	0	0	32	7	10	0
28	40	26	14	23	10	15	10	0	35	23	10	0
29	20	6	5	9	16	9	20	20	15	18	15	0
30	45	33	15	9	16	10	5	4	25	40	4	0
31	60	26	27	20	18	14	10	14	20	18	25	0
32	50	26	35	20	14	20	0	0	23	20	20	5
33	50	13	10	12	12	18	0	0	10	20	9	0
34	0	20	19	13	0	0	10	17	8	10	0	0
35	30	15	18	12	9	7	15	12	13	20	17	0
36	30	18	7	0	6	0	5	4	25	15	0	0
37	35	12	0	17	22	9	18	16	20	20	7	10
38	25	21	0	0	13	5	10	17	0	13	10	0
39	25	23	10	4	13	10	3	7	20	15	4	10
40	30	14	5	12	24	5	15	20	20	20	27	0
41	45	26	0	5	7	0	17	25	20	9	0	0
42	60	38	14	12	10	25	0	0	30	25	17	10
43	20	20	7	4	13	14	10	10	0	0	9	0
44	30	30	10	10	18	10	10	27	35	25	17	0
45	35	28	25	18	23	20	15	22	30	17	15	20
46	15	24	4	9	13	22	20	10	20	13	8	0
47	25	14	4	4	5	10	15	12	0	15	17	0
48	5	4	*	*	0	0	0	0	8	10	15	0

*Indicates that the student was absent on the day of the examination.

Students No. 1-23 experienced concrete instruction.

Students No. 24-48 experienced formal instruction.

TABLE E-3

SPEARMAN-BROWN SPLIT HALF RELIABILITIES OF CONTENT EXAMINATIONS

Content Examination	Multiple Choice r_{hh}	Multiple Choice r_{xx}	Free Response r_{hh}	Free Response r_{xx}
Static Electricity	0.038	0.073	0.412	0.584
Current Electricity	0.421	0.593	9.458	0.628
Light & Optics	0.432	0.603	0.140	0.246
Sound	0.134	0.236	0.682	0.811
Magnetism	0.308	0.471	0.462	0.632
Electro-magnetism	0.178	0.302	0.205	0.340