A STUDY OF TEACHER, METHODS, AND COGNITIVE STYLE EFFECTS ON ACHIEVEMENT OF SCIENCE PROCESS SKILLS

by

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ABSTRACT

The purpose of this investigation was to answer two basic questions, namely, (1) Is the mental factor of Field Dependence a significant predictor of achievement of science process skills? and (2) To which of the three different levels of Field Dependence, Global, Middle or Analytic, are the two major methods of teaching Science 8 in British Columbia schools, (ISC, Labtext) best suited?

This investigation grew out of the author's classroom teaching experience. It was observed that in classes of grade 8 students using "*Labtext in Science, Book 1*" [Cannon et al., 1968] as a guide, some students seemed to experience difficulty in performing the investigations, while certain other students found these investigations to be exciting and rewarding. Similar observations were made in classes using the text "*Introducing Science Concepts in the Laboratory*" [Schmid, 1971]. The different learning styles appeared to have no relation to the "intelligence" of students as measured by standard IQ tests. Some students in both classes who experienced difficulty possessed a relatively high IQ.

The writer sensed that Witkin's concept of Field Dependence [Witkin et al., 1962] could be a useful way of explaining why one method of science instruction could suit the learning style of some students and not others. In order to investigate this notion more systematically, two methods of teaching embodied in the two different texts identified above were, first of all, carefully delineated. Briefly, the Labtext

method was described as a learning situation which allowed much freedom of individual action during an investigation, while the ISC method was described as a structured learning situation in which specific instructions were given and guiding questions were asked. On the basis of Witkin's findings [Witkin, 1969] it was felt that field dependent (global) students would function better with the ISC method while field independent (analytic) students would be more successful with the Labtext approach. Cognitive style was assessed by means of the *Hidden Figures Test*, and achievement was measured by means of the *Test of Science Processes*.

The experimental phase of this study took place over a period of one complete school semester. At the outset students were randomly assigned to six classes of which the author taught four, with two classes assigned randomly to each method. A second teacher taught two classes, randomly assigning one class to each method. The involvement of two different teachers allowed a study of the effect of teachers on achievement, and the fact that one teacher taught two classes with each method provided a situation in which the effect of one teacher using the same methods with different classes could be studied.

The expected superior performance of analytical students compared to global students in terms of achievement in science process skills was confirmed. No evidence of overall superiority of one method of teaching over the other was found. There was no significant overall teacher effect, however, the three-way interaction effect

showed that the effectiveness of a particular teaching method for a particular cognitive style varied according to the teacher. No firm conclusion regarding the interaction effects could be reached due to several intervening variables. The possibilities of interaction between test format and the cognitive style of students, and the interaction between the cognitive style of the student with that of the teacher were discussed.

The implications of the construct of cognitive style for junior secondary science education were discussed in terms of methodological reform, and much needed research to determine the nature of the effect of a teacher's cognitive style on classroom learning situations was suggested.

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CHAPTER I

INTRODUCTION

1.0 THE PROBLEM

1.1 The General Problem

The general problem investigated in this study was the effects of different teachers, methods of instruction and learning styles on the achievement of science process skills. More specifically, some learners seem to require considerable direction and guidance in order to learn to use and understand the processes of science (e.g. observing, comparing, measuring, experimenting), while others seem to be more successful when allowed much individual freedom to pursue their own modes of learning the processes.

Research evidence dealing with the problem of identifying a single, reliable, multipurpose teaching strategy that can be used with confidence that it is the best approach is remarkably ambiguous [Joyce and Weil, 1972, p. 4]. Cronbach [1967] called for the abandonment of the search for the one best instructional method and recommended that research should aim for the systematic adaptation of methods to differences in learning styles among the learners. Mitchell [1969] adds that if significant interactions between various methods of teaching and students' individuality were discovered they would have considerable influence on educational planning.

1.2 Importance of the Problem

Among the aims of teaching science in British Columbia schools is the objective that science teaching "should develop abilities that make young people increasingly independent investigators and learners" [Province of British Columbia, 1968, p. 4]. Consequently, students entering the junior secondary school (grade eight) for example, can be expected to have acquired the abilities to varying degrees for various reasons, such as differences in learning styles. It would seem reasonable to assume that teaching methods at the secondary school level should be adapted to meet these differences. Clearly, research is needed to uncover individual differences in learning styles with respect to these abilities and attempt to meet these differences with teaching strategies which can facilitate the further development of these abilities. This study was an attempt to determine individual differences in learning styles of students entering the junior secondary school (grade eight) in terms of dependency on the teacher and to study the effects of two different teaching strategies adapted to take these differences into account. Witkin [1969] defined a person's "cognitive style" as the "characteristic, self-consistent way of functioning that an individual shows across perceptual and intellectual (i.e. cognitive) activities." A battery of tests described by Witkin et al., [1962] identifies a continuum of cognitive styles characterizing a population. At one end of the continuum are people classed as field dependent. Such people have a mode of perception in which the overall organization

of a prevailing perceptual field is dominant and parts of the field are indistinguishable from each other and experienced as fused with their background. This mode of perception is said to be "diffuse" or "global." At the other end of the continuum is the field independent person who will perceive parts of the field as discrete and the field as a structured whole. This kind of perception is referred to as "articulated" or "analytical." For example, a young, highly global student was handed a tray of batteries, wires and bulbs and instructed to see what he could find out about differences in the electrical resistance of different wires with this apparatus. One of his first questions was "what is the tray for?" An analytical student would immediately recognize the tray as a non-operant factor in this investigation. A tendency towards a more global or more analytic mode of functioning pervades a person's cognitive activity from childhood to adulthood.

As early as age five, children have a tendency toward either a global or an analytical perceptual mode. Longitudinal studies [Faterson and Witkin, 1970] have shown that intellectual development can be categorized by a progression from global to analytical modes of functioning. Relative to his age group, however, a child's position on the continuum from global to analytical remains constant. That is, the group as a whole moves towards greater articulation while the cognitive style of the individual remains constant relative to his age group.

Witkin's construct of cognitive style has some important implications for science teaching. Field dependent children exhibit

dependence on others for guidance, inability to structure a set of stimuli, inability to see alternate uses for the familiar, inability to resist persuasion by authority, and the inability to adopt analytical procedures when dealing with problems. Field independent children are less conforming, and more analytical and self-directing in their classroom behavior. [Witkin, 1969, p. 224] speculates that "emphasis in teaching on both specificity and structuring would be most conducive to the development of articulation." Hence, for children categorized as perceptually global, the teacher should begin with a structured learning situation in which specific instructions are given and guiding questions are asked. Since these students are unable to adopt analytical procedures, they must be helped. Analytical students, being more self-directing, do not require as much structure in learning situations as global children, and can be given considerably more freedom of choice and action right from the start.

In relating the construct of cognitive style to science education, it is clear that the aims of science teaching at the grade eight level include the development of a style of learning consistent with Witkin's concept of cognitive style. Implicit or explicit in the lists of objectives for many science courses today is the attainment of skills in the processes of science [Brown, 1968; American Association for the Advancement of Science, 1968; Nay, et al, 1971]. This objective has been stated in a variety of ways, ability to think scientifically, ability to use scientific methods, ability to think critically, ability to think reflectively, or the attainment of skills

in problem solving. The curriculum guide for teachers of grade eight science in British Columbia [Province of British Columbia, 1968] recommends that science teaching should develop an understanding of the methods of science and a disposition to use the methods of science whenever appropriate. In this way students will become increasingly independent investigators [Province of British Columbia, 1968, p. 4].

Gagné [1963] states that since enquiry is the most critical type of scientific activity, then the teaching of the underlying methods of enquiry is one of the most essential objectives of science education. Only a small number of the students in the junior high school will enrol in senior science courses and of these, very few will proceed into a career in science. Keeping in mind that it is very difficult to forecast what scientific content a child should know, Sears and Kessen [1964] describe science as a "structured and directed way of answering questions" and state that "it is a pedagogical triumph to teach the child the facts of science in relation to the procedures of scientific enquiry."

For the vast numbers of students who will never undertake a scientific investigation, Sears and Kessen [1964] believe that a child who has been well taught to understand and use the processes of science will approach the problems of life with the same spirit that he adopts towards scientific theories. The belief that difficult problems may be solved by scientific analysis will develop an optimistic appreciation of the strength of enquiry. Gagné (1970) states that students need to engage in systematic and deliberate practice in the activities of

scientists where they will learn generalizable process skills which carry the promise of broad transferability across many subject areas.

Tyler [1968] observed that there are vast differences among children in the way they attack a problem. Some children make random-like efforts and are unable to plan out a method of working in advance. Tyler advocates research to discover the best conditions under which analytical cognitive processes will develop. Science enquiries, Tyler suggests, must be constructed so as to build on a limited cognitive level and at the same time help to raise the level to greater flexibility in modes of enquiry. Cronbach [1967] called for the abandonment of the search for the one best instructional method and recommended that research should aim for the adaptation of methods to pupil differences.

Sieben [1971] found that in classes of elementary school children (grades 5, 6, and 7) where students were given considerable freedom in their approach to investigating natural phenomena, students categorized as perceptually global achieved lower scores on a test of science processes than did analytically perceptual children. It may well be that field dependent children who rely on others for guidance could profit more from a teaching strategy designed to improve their attainment of science process skills and that children who have an analytical cognitive style will gain more from a teaching strategy that offers more individual freedom of investigation at the secondary school level.

1.3 The Specific Problems

The specific questions in the order in which they were investigated in the study are as follows:

1. What effect do different cognitive styles of students have on achievement of science process skills?
2. What effect do different approaches to teaching science to grade eight students have on achievement of science process skills?
3. What effect do different teachers have on student achievement of science process skills?
4. Are there any interaction effects between cognitive style and method in terms of achievement of science process skills?
5. Are there any interaction effects between cognitive style and teachers in terms of achievement of science process skills?
6. Are there any interaction effects between method and teachers in terms of achievement of science process skills?
7. Are there any interaction effects between cognitive style, method, and teachers in terms of achievement of science process skills?
8. What is the correlation between post-test scores and delayed post-test scores on the science process test?

The author felt that answers to these questions would provide much useful information to teachers of grade eight science. Very little research was found which attempts to adapt specific methods of teaching to the individual differences of students in this age group in terms of cognitive style.

At present in British Columbia, there are in use two student texts, both of which are based on the objectives of science teaching set forth by the Department of Education [Province of British Columbia, 1968]. The first text, "Introducing Science Concepts in the Laboratory" [Schmid, 1971], hereafter referred to as "ISC", is designed in such a way that each investigative activity is accompanied by eliciting questions and specific directions to be followed by the student. The other text, "Labtext in Science, Book 1" [Cannon et al., 1968], hereafter referred to as "Labtext," confronts the student with a problem and attempts to involve the student in a period of self-directed inquiry and data collection during which a minimum of guidance is given. Afterwards the student is asked to generate ideas or hypotheses to explain his observations.

The presence of these two texts, and the different approach which each seemed to advocate,[1] evoked the need to know which was more suitable for certain types of students. From experience with these texts the author felt that there was some commonality among

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[1]The two teaching approaches are described in detail in Chapter III.

students who were successfully using the texts, but could not clearly identify what it was. Witkin's construct of cognitive style and the characteristics of field dependent and field independent children appeared to be a promising way of accounting for students who were having more success with one text than the other.

2.0 METHOD OF STUDY

2.1 The Procedure

A suitable experimental situation existed in the school where the author was teaching in Delta, British Columbia. Students in grade eight were randomly assigned to six science classes of approximately thirty students each and were made available to the investigator for the pruposes of this study. Four of these classes, selected at random, were assigned to the investigator and the remaining two classes to a second teacher who agreed to participate in the investigation.

During the first weeks of school, beginning in September, 1972, two tests were administered to all six classes. The first test was a measure of field dependence and field independence,[2] and the second test was the *Test of Science Processes*[3] [Tannenbaum, 1971]. The tests were administered to all classes by the investigator, each class being tested separately in the classroom situation. The

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[2]The Group Hidden Figures Test is described in Chapter III.

[3]The Test of Science Processes is described in Chapter III.

results were recorded but not analyzed by the two teachers involved in the study until the conclusion of the teaching phase of the study.

Teachers randomly assigned their classes to the two different teaching approaches, resulting in three classes for each approach. During the five months of the first school semester (September to January), classes were taught according to detailed lesson plans for each teaching strategy.[4] Independent observers made random checks on the classroom behavior of both teachers to ensure that the teachers were following the lesson plans as prepared. At the end of the semester the *Test of Science Processes* was again administered as a post-test to each class. This same test was also administered at the end of April to provide a measure of the level of achievement of science process skills retained after instruction had ceased.

2.2 Analysis of the Data

The computing facilities of the University of British Columbia were used to analyze the results of this investigation. The tests were scored and item analyses were performed using the program UBC ED:TIA which also provides a KR-20 coefficient of reliability. The statistical hypotheses were tested using an analysis

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[4]A copy of the detailed lesson plans for the three units taught by each strategy is contained in Appendix C.

of variance procedure. Computations were carried out using the program UBC: MULTIVAR. A graphical analysis of interaction effects was also performed. The latter analysis sought to clarify the specific nature of interaction effects between teachers, teaching method and cognitive style.

3.0 DESCRIPTION OF TERMS

The terms and phrases used in this study whose common meanings may be unclear for the purpose of this study are defined as follows:

Cognitive Style: The self-consistent ways of functioning a person shows in his perceptual and intellectual activities.

Field Dependence: The lack of ability to disembed a stimulus figure from an irrelevant but organized stimulus background or field.

Global: An adjective to describe subjects for whom the organization of the field as a whole dictates the way in which its parts are experienced; that is, a field dependent person. For example, after a class experiment in which the response of radish seedlings to light was tested, a list of observations from the experiment was compiled. Global students had difficulty in isolating those observations which were relevant to the problem and found great difficulty in reaching any valid conclusion based on the data.

Articulated or Analytical: Synonymous adjectives to describe a person who experiences parts of a field as discrete and the field as a whole as structured; that is, a field independent person. In the example for "global" above, analytical students were not only able to identify readily those observations pertinent to the problem, but were also able to reach a valid conclusion based on those observations.

Science Processes: The procedures followed by an investigator during a scientific enquiry. For example, observing, comparing, classifying, quantifying, measuring, experimenting, inferring and predicting [Tannenbaum, 1971].

4.0 LIMITATIONS OF THE STUDY

The instruments used in this study to establish cognitive style and to measure achievement of science process skills were group tests. The KR-20 coefficient of internal reliability for the test of field dependence (*The Hidden Figures Test*) was found to be 0.92, and for the *Test of Science Processes* analysis of the pre-test and post-

test data yielded KR-20 coefficients of 0.86 and 0.88 respectively.[5] Although these results are encouraging, documentation of validity and reliability is quite limited (see Chapter III). The results should therefore be interpreted with caution.

A limitation of this study is the generalizability of the results. The grade eight students used in this study constitute a random sample of sixty percent of the population of grade eight students in a particular suburban school. As such, the results should be applied with discretion to students not in this population.

In terms of scope, only two teaching strategies were investigated. A competent teacher often has a larger repertoire of teaching methods to draw on, among which some may be better adapted to differences in cognitive style than those investigated in this study. However, the two approaches studied here are frequently used not only in teaching science, but also across all subject areas where the inquiry approach plays a major role. The more directed ISC approach is quite similar to Taba's more general *Inductive Model* for teaching social studies studies [Taba, 1967], while the Labtext approach bears strong resemblance to Suchman's *Inquiry Training Model* [Suchman, 1966].

Other areas of equal concern to science teachers are the development of laboratory skills, scientific concepts and principles, and the development of favorable attitudes towards science. Further parallel studies are needed to investigate the effects of different teaching strategies in these areas.

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[5]Further descriptions and analyses of these tests are contained in Chapter III.

CHAPTER II

CONTEXT OF THE STUDY

1.0 EFFECTS OF COGNITIVE STYLE ON ACHIEVEMENT

1.1 Origins of Cognitive Style

Many studies have shown that there is a relationship between cognitive style and the way in which students learn and teachers teach, and in how students and teachers interact in the classroom. Differences measured by the *Rod and Frame Test*, the *Body Adjustment Test* and the *Embedded Figures Test* have been found to be significantly related to differences in cognitive functioning and in particular, analytical functioning [Witkin et al., 1962].

Some work has been carried out to determine the origins of individual differences in cognitive style. Studies of family experience of children who are relatively field dependent or field independent have demonstrated that the kind of relationship the child has with his mother while growing up is very influential in determining his cognitive style [Dyk, 1969; Dyk and Witkin, 1965; Witkin et al., 1962]. For example, the encouragement of autonomous functioning seems most closely associated with the development of a more analytic cognitive style. Indeed, the effect on cognitive style of different practices in child-rearing has been shown in several cross-cultural studies. Dawson [1967] compared two tribal groups in

Sierra Leone, the Temne and the Mende, which differ greatly in socialization emphases in child-rearing. Temne children are subjected to severe discipline, and conformity to adult authority is enforced, whereas Mende children are seldom subjected to physical punishment and great emphasis is placed in giving the child responsibility at an early age. As expected, Dawson found that Temne children were relatively more field dependent than Mende children. Berry [1966] compared the Temne of Sierra Leone with the Eskimo of Baffin Island. Among the Eskimo, punishment of children is generally avoided and extreme freedom is allowed the individual child. There is strong encouragement of personal self-reliance, individualism and ingenuity, and discouragement of dependence and incompetence. Berry found the Eskimo group to be strikingly more field independent than the Temne group. The evidence accumulated from these cross-cultural studies demonstrates impressively that socialization factors are undoubtedly of overwhelming importance in the development of individual differences in cognitive style. Witkin and his associates are presently pursuing the possibility that genetic factors enter into the development of cognitive style. Three studies [outlined in Witkin, 1972] are presently being conducted to investigate the possibility that if genetic factors are involved in field dependence, the sex chromosomes are especially likely to be implicated.

1.2 Development of Cognitive Style

Witkin, Goodenough and Karp [1967] have demonstrated by means of both logitudinal and cross-sectional studies that the cognitive style of an individual is surprisingly stable relative to his age group. A progressive increase in extent of field independence was evident in subjects up to age seventeen, with no further change from seventeen to twenty-four. However, relative to the age group, children remained remarkably stable in their mode of perception. These stability studies dealt with subjects who themselves were reared in stable family and environmental settings and findings as yet are not generalizable to unstable child-rearing conditions. However, findings seem to indicate that if educators wished to alter modes of perception, the children involved would have to be quite young.

Several studies with adults have shown marked stability of cognitive style. Attempts have been made to alter field dependence experimentally. In several studies [cited by Witkin, Goodenough and Karp, 1967] the effects of training, stress, and drugs were investigated with the result that test-retest scores on measures of field dependence were remarkably stable.

1.3 Sex Differences

Witkin and his associates [1962] have repeatedly found sex differences on tests of field dependence. Females tend to be more global than analytical. In the *Rod and Frame Test*, girls and women are likely to tilt the rod farther towards the tilted frame

in order to perceive the rod as upright, and in the *Embedded Figures Test* they find it harder to break up the complex configuration and find the simple figure within it. On these tests the difference in performance between the sexes is small in magnitude compared to the range of individual test results within each sex, but it is clearcut and pervasive, although they may not occur in very young children [Goodenough and Eagle, 1963] nor in geriatric groups [Schwartz and Karp, 1967]. Sex differences have been found in many varied cultural settings, including the United States and Western European countries [Witkin et al., 1962] and Sierra Leone [Dawson, 1967] although not among the Eskimo [Berry, 1966]. Witkin [1967] speculates that sex differences may arise from different emphasis on socialization, since boys in many cultures are encouraged to be independent and assertive, while girls are encouraged to be more dependent. The exception found among the Eskimo may arise from the fact that women are not treated as dependent and very loose controls are exercised over them. Genetic factors are also being investigated as a possible source of sex differences [Witkin, 1972].

1.4 Relation of Cognitive Style to General Intelligence

Three main factor components of the commonly used Weschler scales have been identified [Cohen, 1957; 1959]. Performance on tests of field dependence has been found to show low, non-significant correlations with scores on a verbal-comprehension cluster (Vocabulary, Information and Comprehension), and an attention-

concentration cluster (Digit Span, Arithmetic and Coding) of Weschler subtests. However, field dependence measures correlate highly with an analytical cluster of subtests (Block Design, Object Assembly and Picture Completion) which tap the same kind of analytical abilities as do the tests of field dependence [Goodenough and Karp, 1961]. Witkin [1969] points out that "children who are field independent are superior to field dependent children only on the analytical cluster of subtests. . . . We cannot say that field independent children are superior in 'general' intelligence" [Witkin, 1969, p. 205].

1.5 Characteristics of Field Dependence

Field dependence is a manifestation in the perceptual sphere of a broad dimension of personal functioning which extends into the sphere of social behavior. In forming their attitudes on an issue, field dependent people are especially prone to be guided by the positions attributed to an authority figure or peer group [Bell, 1964; Deever, 1967], hence they are selectively attentive to the human content of their environment, and studies have found that, in comparison with analytical people, they spend more time looking at the faces of those with whom they are interacting [Konstadt and Forman, 1965]. Since field dependent people use external sources of information for self-definition this fact is not surprising since the face is a major source of information about what others are feeling and thinking. Many studies indicated that field dependent children would be prone to experience difficulty in unstructured learning situations. From case studies, Witkin and his associates found children of "limited

differentiation" (highly field dependent) to be characterized by the following attributes:

> . . . poverty of resources, lack of enterprise and initiative, underdeveloped interests, lack of well-structured controls and defenses and marked dependence on others [Witkin et al., 1962, p. 268).

The scores of students on interest inventories and vocational preference inventories have been examined in relation to field dependence at various educational levels [Chung, 1966; DeRussy and Futch, 1971; Glatt, 1969; Pierson, 1965]. A consistent finding of these studies is that the more field independent students favour vocations in which analytical skills are called for (such as the sciences, mathematics, engineering, etc.) while the more field dependent students avoid such domains. Reflecting the highly developed social skills of field dependent students, the above studies also found that these students preferred vocations in which day-to-day work requires involvement with people (such as social sciences, counseling, elementary school teaching, selling real estate, etc.).

1.6 How Students Learn is Related to Cognitive Style

In the light of the field dependent person's need for structure from external sources it seems reasonable to predict that such students would learn more in terms of skills, processes, and content in a supportive setting than in an unstructured setting [Witkin, 1972]. Many studies have shown that relatively field dependent students, reflecting their concern with the social surround and their reliance

on external standards, were highly affected in their task performance by praise and criticism. On the other hand, relatively field independent students, less oriented to the social environment and more prone to use inner standards, tended to be much less influenced [Konstadt and Forman, 1965; Ruble and Nakamura, 1972; Fitz, 1970; Paclisanu, 1969; Randolph, 1971].

In terms of teaching methods, Grieve and Davis [1971] made a comparison of the amount of geography learned with different teaching methods by extremely global and analytical grade nine students. Two teaching approaches were used, one an expository method, and the other a discovery method where learning took place through interaction with the teacher. One finding was that the more global the student, the more likely he was to benefit from discovery instruction, a context congenial to the social orientation of global students. In other teaching areas, adaptation of teaching methods to cognitive styles has proved fruitful. Spitler [1970] spelled out alternative methods of teaching mathematics to field dependent and field independent students, each method exploiting the cognitive style of the student. Relevant to this question of how to teach, is the repeated observation that children with learning disabilities, particularly in reading, tend to be field dependent [Robbins, 1962; Keogh and Donlon, 1972].

1.7 Matching the Teacher's Cognitive Style with that of the Student

DiStefano [1969] studied the consequences of match or mismatch in cognitive style between teacher and students. Teachers and students matched for cognitive style described each other in highly positive

terms, whereas teachers and students who were mismatched tended to describe each other negatively. Witkin [1972] cites several other examples of similar effects of match or mismatch in other situations. In patient-therapist interactions, and in interviewer-interviewee interactions, positive feelings developed between those who were relatively similar in their field dependence.

Witkin and his colleagues are at present studying three possible reasons why persons matched in cognitive style tend to get along better [Witkin, 1972]. The first reason is that matched people have shared foci of interest. Field dependent people share the tendency to attend selectively to the social content of the environment, while field independent persons share an interest in the more impersonal, abstract aspects of their surroundings. Such mutual interest should make for a positive outcome in their feelings for each other. The second reason for greater mutual attraction is similarity in personal characteristics, including even the manner of dress. White and Kernaleguen [1971] found that field dependent female students tend to wear clothes commonplace for their peer group, whereas field independent students wear relatively unusual clothes. The third reason is similarity of communication modes, making for easier and more effective communication. Several studies [cited by Witkin, 1972] have found that field dependent persons make fewer self-references in their speech than field independent people.

Another study in progress [cited in Witkin, 1972] is examining teacher-student interactions under conditions of match or mismatch of cognitive style, in an attempt to identify the

specific interactions which lead to either positive or negative mutual evaluation of teachers and students.

1.8 Summary

Individual differences in performance on tests of perception have been found related to differences in cognitive functioning and in analytical functioning, and a tendency towards either field dependence or field independence is a stable personal characteristic. Cross-cultural and in-depth studies have shown that an individual's cognitive style is linked closely with differences in child-rearing in the early stages of development and possibly genetic differences. Sex differences have led to speculation about sex-linked genes also being involved.

Field dependence is associated with highly developed social skills and difficulty in unstructured situations. Sensitivity to the social environment and the use of the prevailing social frame to define the self has been shown to affect vocational preference. Teaching methods have been adapted on this basis to students' cognitive styles and have been shown to effect differences in learning. Studies have also shown that people matched in cognitive style get along better. This mutual attraction is especially important in the educational setting. In this regard, however, the following cautionary note should be observed:

> A decision on which student-teacher combination achieves the best learning results obviously requires consideration of many other cognitive styles, as well as variables of other sorts. To make appropriate decisions about teacher-student mixes, we need to build up a fund of knowledge, gained through systematic research, on the many other variables that influence teaching and learning effectiveness [Witkin, 1972, p. 42].

2.0 DESCRIPTION AND COMPARISON OF THE TEACHING METHODS

The purpose of this section is to distinguish between the two methods of teaching Science 8 used in this study. This distinction will be made in terms of their resemblances to two different teaching models which are already well-established in education.

2.1 Description of Suchman's Inquiry Training Model

Suchman's model of inquiry training begins with the assumption that inquiry is "the pursuit of meaning" and that it is motivated by the desire "to obtain a new level of relatedness between and among separate aspects of one's consciousness" [Suchman, 1966a, p. 178]. Suchman believes that the individual, upon encountering a puzzling or discrepant event, needs to gather and study data relevant to the event and to put it together in new ways so as to make the event meaningful. The goals which Suchman sets for this program are to stimulate and support the pursuit of meaning, create conditions in order to make this pursuit possible and productive, and encourage inquiry into the inquiry process itself, since conscious awareness of the process and strategies of inquiry is an essential aspect of autonomous

inquiry [Fish and Goldmark, 1969].

The inquiry program developed by Suchman seeks to enable the learner to direct and control his own learning. Essentially, three conditions have been identified which are necessary for inquiry to occur [Suchman, 1964]. Firstly, children need a focus for their attention: "Focusing and refocusing is a continuous job for the teacher, by raising new questions that reveal new discrepancies" [Suchman, 1966b, p. 16]. Secondly, the teacher must create a free environment by "allowing each child to pursue new meaning and new understanding in his own way, to construct theories and explanations in his own terms, and to progress at a rate that satisfies the learner" [Suchman, 1966b, p. 15]. Thirdly, the child must have a responsive environment where, when he reaches out for data, he must procure something.

The following chart, Table II-1, summarizes Suchman's Inquiry Training Model.

TABLE II-1

SUMMARY CHART: INQUIRY TRAINING MODEL

Syntax:	Phase 1: Encounter with the problem. Phase 2: Inquiry through questioning, verbal or actual experimentation and generation of hypotheses. Phase 3: Analysis of inquiry
Principles of Reaction:	The Teacher: 1. insures that questions are phrased so that they can be answered in yes or no and that their substance doesn't require the teacher to do the inquiry. 2. acts to provide a free intellectual environment. 3. responds to learners' requests for information and provides maximal stimulus for inquiry by focusing, refocusing, or summarizing the inquiry.
Social System:	Highly structured. Teacher is the controller of the interaction and prescribes the inquiry procedures. However, the norms of inquiry are those of cooperation, intellectual freedom, and equality.
Support System:	The optimal support is a prepared set of confronting materials and a training agent who understands process and strategies of inquiry.

[Source: Joyce and Weil, 1972, p. 150]

In the classroom, inquiry training has three phases [Suchman, 1966b]. The first phase begins with the presentation of a problem by film or demonstration. This offers the initial motivation since many of the films or demonstrations present a discrepant event. Focusing questions are asked which challenge students to formulate and test their own theories to explain the event. Then follows a

period of inquiry in which students gather data and try to generate ideas or hypotheses to account for the event. Students may question the teacher, but the questions must be phrased in such a way that they can be answered "yes" or "no." The teacher, however, does not accept or reject statements of theories, or reply to questions that attempt to obtain the teacher's approval of a theory. At all times the teacher responds positively to the student and neutrally to the product of the student's thinking. In the third phase, the teacher helps the students to examine the inquiry process itself, to come to understand how knowledge comes into being, where theories come from and how they can be appraised. During this phase, the teacher must be able to identify and use "teachable moments" when new ways to approach puzzling situations may be introduced most effectively.

In Suchman's inquiry training model, the learning of specific concepts such as density, pressure, etc., is subordinate. The program is designed specifically to teach children to improve their own strategies of inquiry. The teacher nurtures a spirit of creativity and independence or autonomy in learning. The importance of these teacher functions is indicated in a study reported by Suchman [1964] in which children who rated high on cognitive control, impulsivity, and autonomy were more effective inquirers than children who were low on any of these three factors.

2.2 Description of Taba's Teaching Model

Hilda Taba's social studies curriculum addressed itself to the multiple objectives of developing basic knowledge, thinking,

attitudes, and skills. Development of different patterns of thinking has long been considered important in curriculum construction. However, Taba felt that development of thinking skills had been poorly implemented because of insufficient analysis of the processes and skills involved [Taba, 1966].

Taba's inductive model for teaching social studies was based on the assumption that certain ways of thinking, such as inductive or deductive, can be learned, therefore they can be taught provided the specific processes and skills comprising a particular mode of thought can be described. Taba described the sequence of thought processes, which she called "covert mental operations," that are involved in inductive thinking. The sequential nature of the operations is very important since, in order to master certain thinking skills, certain other earlier ones must be mastered and this process cannot be reversed.

In order to stimulate students to perform these covert mental operations, Taba identified certain teaching moves in the form of eliciting questions which cause the student to perform an "overt" activity such as enumerating, grouping, predicting, etc., and if the student is successfully performing these overt activities then he must of necessity also be performing the associated covert mental operations. The teacher's function is to ask eliciting questions at the appropriate time so that the student will be stimulated to perform the necessary operations. Hence, the teacher must monitor the ways in which students are processing information and use eliciting questions to move the activities on to the next phase.

Table II-2 summarizes Taba's inductive model. Three cognitive tasks are identified, each containing three phases of overt activities. Also shown are the covert mental operations and examples of the eliciting questions to be used by the teacher.

TABLE II-2

SUMMARY CHART: TABA'S INDUCTIVE MODEL

Syntax:

Cognitive Task 1: Concept Formation

Overt Activity	Covert Mental Operation	Eliciting Questions
1. Enumeration and listing	Differentiation	What did you see? hear? note?
2. Grouping	Identifying common properties, abstracting	What belongs together? On what criterion?
3. Labeling, categorizing	Determining the hierarchical order of items. Super- and sub-ordination	What would you call these groups? What belongs under what?

Cognitive Task 2: Inferring and Generalizing

Overt Activity	Covert Mental Operation	Eliciting Questions
1. Identifying points	Differentiating, distinguishing relevant information from irrelevant	What did you note? see? find?
2. Explaining identified items of information	Relating points to each other; establishing cause and effect relationships	Why did so-and-so happen? Why is so-and-so true?
3. Making inferences or generalizations	Going beyond what is given; finding implications; extrapolating	What does this mean? What would you conclude? What generalizations can you make?

Cognitive Task 3: Application of Principles

Overt Activity	Covert Mental Operation	Eliciting Questions
1. Predicting consequences, explaining unfamiliar phenomena, hypothesizing	Analyzing the nature and the dimensions of the problem or condition	What would happen if . . . ?
2. Explaining and supporting the prediction and hypotheses	Determining the causal links leading to a prediction or hypothesis	Why do you think this would happen?
3. Verifying the predictions	Using logical reasoning to determine the necessary conditions and the degree of universality of the prediction	What would it take for so-and-so to be true? Would it be true in all cases? At what times? etc.

Principles of Reaction:

The teacher:

1. must monitor the ways students are processing information.
2. match eliciting questions to the specific phases within each cognitive task.
3. ensure that the cognitive tasks occur in the optimum order.

Social System:

The atmosphere is cooperative with much pupil activity. The sequence of activities is determined in advance and the teacher is in a controlling position and is the initiator of phases.

Support System:

Large quantities of raw data must be available so that students can organize and process the data in more complex ways, and to increase the general capacity of their systems for processing data.

[Source: Joyce and Weil, 1972, pp. 126-136]

2.3 Comparison of the Labtext Teaching Method with Suchman's Inquiry Training Model

The Labtext method of teaching has three phases. The first phase consists of confronting the student with a problem, if possible in such a way as to puzzle the student. A discussion of the problem is guided by the teacher with the purpose of motivating students to investigate. In the second phase, students work with the apparatus and equipment in any manner which they feel will help to solve the problem. They gather all data which seems relevant. When their data-gathering is complete they try to generate ideas or hypotheses to explain or solve the initial problem. During this time the teacher responds only to those questions which may be answered "yes" or "no," and does not respond to any questions which will tell the student how to perform the inquiry. The teacher may, however, supply necessary information on request. The teacher must respond positively to the student so as to encourage all lines of thought and inquiry, but must respond neutrally to the products of the student's thinking.

In the third phase, the teacher and students analyze the results of the inquiry and students may be required to answer some written questions concerning these results, but more emphasis is placed on analyzing the methods of inquiry used by the students than on the actual results of the inquiry. The teacher helps the students to examine different methods of inquiry and encourages them to apply these methods to the same problem if applicable.

A comparison of the Labtext method with Suchman's inquiry training model reveals very few differences. Both methods have the same three phases with the function of the teacher being the same in both methods. In phase one, the Labtext problems posed may not always appear as discrepant events as in the Suchman model. In phase two the two methods are virtually identical, while in phase three the only difference is that a little more emphasis may be placed on the results of the inquiry in the Labtext method, but at all times the examination and analysis of the methods of inquiry receive at least equal emphasis.

2.4 Comparison of the ISC Teaching Method with Taba's Inductive Model

The ISC method of teaching has three phases. The first phase consists of confronting the student with a problem and, by discussion, the teacher tries to arouse students' interest in solving the problem. In the second phase students are supplied with specific written instructions which tell the students exactly how to manipulate the apparatus and materials. Eliciting questions are provided whenever students should observe or measure a property or characteristic. During this time the teacher ensures that all students are following the instructions and answering the questions. If necessary the teacher may provide further oral questions which elicit the intended behavioral response from the student. The questions also guide the student in forming hypotheses and in drawing inferences. In this way

the student is led through the inquiry process. The questions help him to observe, enumerate, group, categorize, identify relevant information, infer, predict, and hypothesize, etc.

The third phase of the ISC method consists of analyzing the results of the inquiry. Teacher and students together discuss the data collected and the answers to questions dealing with generalization and application of the results. Students then answer a series of written questions which review the results of the discussion.

The similarity between the ISC method and Taba's model lies essentially in the way eliciting questions are used to lead students through the inquiry. Taba emphasized a necessary sequence of activities and assumed that each activity is accompanied by an underlying mental process. The required sequence of activities is moved along by the teacher's eliciting questions. Similarly, the ISC method uses eliciting questions to move from one step in the inquiry process to the next.

2.5 Summary of Major Differences between the Labtext and ISC Methods

The following charts, Tables II-3 and II-4 summarize the syntax, principles of reaction, social system, and support system for each of the two methods. From the Tables it can be seen that both methods are similar in Phase One, where the student is confronted with the problem. Another similarity is the atmosphere of cooperation that exists between the teacher and students.

The major differences between the methods lie in Phases Two and Three. Phase Two is essentially a time of experimentation, data

collection, and formulation of ideas and hypotheses. In the Labtext method, students collect whatever data they feel is necessary to explain the problem and they process this data in their own way and try to generate hypotheses. They refrain from asking direct questions of the teacher, and the teacher avoids asking eliciting questions of the students. The teacher encourages any line of inquiry relevant to the problem. In the ISC method, experimentation and data collection proceeds according to specific instructions. Eliciting questions guide observations and data-processing along prescribed lines of investigation. The teacher ensures that students are in fact following this procedure. In Phase Three the ISC method places the major emphasis on the analysis of the results while the Labtext method gives a large portion of the emphasis to the analysis of the methods of inquiry.

TABLE II-3

SUMMARY CHART: LABTEXT METHOD OF TEACHING

Syntax:	Phase 1: Encounter with the problem. Phase 2: Inquiry through experimentation. Students manipulate apparatus and equipment in the way they feel will best solve the problem. Phase 3: Teacher and students together analyze the results and the methods of inquiry used.
Principles of Reaction:	The teacher: 1. acts to provide a free atmosphere of inquiry. 2. insures that students' questions are phrased so that they may be answered by "yes" or "no," and that the substance of the questions does not require the teacher to do the inquiry. 3. responds during phase three in such a way as to keep inquiry turned back onto the process of investigation itself.
Social System:	A highly structured social system is necessary inasmuch as the teacher must move the inquiry sessions from phase to phase, however, the students are free to inquire along whatever lines they see fit. The teacher encourages students to initiate inquiry as much as possible.
Support System:	The necessary requirements are a prepared set of materials that confront the student with a problem and a teacher who understands the processes and strategies of inquiry.

TABLE II-4

SUMMARY CHART: ISC METHOD OF TEACHING

Syntax:	Phase 1: Encounter with the problem. Phase 2: Inquiry through experimentation. Students manipulate apparatus and equipment according to prescribed written instructions. Data is collected and hypotheses are generated by answering explicit eliciting questions. Phase 3: Teacher and students together analyze the results of the inquiry.
Principles of Reaction:	The teacher: 1. must provide a cooperative atmosphere and monitor the ways students are performing the inquiry. 2. ensures that students are answering the eliciting questions as the inquiry proceeds. If the written questions are not sufficient for individual students the teacher must supplement them by asking further questions that will guide the student along the required method of inquiry.
Social System:	The atmosphere is cooperative. The sequence of activities is determined in advance and the teacher is in a controlling position and is the initiator of phases.
Support System:	Each inquiry must be well-prepared in advance with specific written instructions provided and eliciting questions asked whenever data is to be collected or processed. The teacher's job is to help students process the data in more complex ways and to increase the general capacity of their systems for processing data.

2.6 Summary

Two models of teaching and the modification of these models for Science 8 classes have been described. The Labtext approach confronts the student with a problem and attempts to involve him in a period of self-directed inquiry after which the inquiry processes are analyzed in an attempt to produce more autonomous functioning among students in future inquiries. The ISC approach is designed in such a way that each inquiry is accompanied by eliciting questions and specific directions to be followed by the students. Witkin [1969] states that emphasis in teaching on both specificity and structuring would be most conducive to development of articulation. Hence, for field dependent or global children, the teacher should provide a structured situation in which specific instructions and guiding questions are given. The ISC teaching method provides such a situation. Analytical students, being more self-directing, will learn better in a situation which allows them more freedom to follow their own ideas. The Labtext approach provides such a situation.

CHAPTER III

METHOD OF STUDY

1.0 SUBJECTS

1.1 Description of the Subjects

All the subjects used in this study were grade eight students enrolled in Science 8 at Delview Junior Secondary School, in School District 37, of the Province of British Columbia. Students in the school are typically from suburban, middle-class homes. In age, the subjects ranged from twelve to fourteen years.

1.2 Selection of Subjects and Classes

Approximately 300 students enrolled in Science 8 in September, 1972, and were randomly assigned by computer to ten different Science 8 classes. Six of these classes were scheduled to take the course in the Fall semester, during which the study was to take place. Of these six classes, four were randomly assigned to one teacher (the writer) and two classes to a second teacher. The number of students in these six classes who were in attendance for the whole semester was 160. These students constituted the sample for the investigation. Table III-1 gives the number of students in each class.

TABLE III-1

NUMBER OF STUDENTS IN EACH CLASS

CLASS	NUMBER OF STUDENTS
1	27
2	25
3	27
4	29
5	26
6	26
	TOTAL 160

2.0 INSTRUMENTS

2.1 Hidden Figures Test

A measure of field dependence was obtained by means of a group version of the *Hidden Figures Test*, Form cf-1 [Buros, 1972, p. 440]. The test consists of 32 items, each of which requires the subject to identify a simple figure within a complex field. Sample items from the test are given in Appendix A.

The test was administered separately to each class by the investigator, and care was taken to ensure uniformity of testing conditions. A trial sheet was given to the students prior to the test in order to familiarize the students with the tasks required in the

test items. The test was administered in two halves, each with a time limit of ten minutes, and a five minute break between halves.

The KR-20 coefficient of internal reliability was calculated for the *Hidden Figures Test* and was found to be 0.92. The test is similar to Witkin's embedded figures tests used in identifying field dependency [Jackson, Douglas, Messick and Myers, 1964] and parts of the test have been used for this purpose by Sieben [1971]. No data on the reliability and validity of the test has been reported by Educational Testing Services, publishers of the test.

2.2 Test of Science Processes

The *Test of Science Processes* (TOSP) developed by Tannenbaum [1971], consists of 96 multiple choice items. Each item is intended to measure a specific science process skill. For example, for the process of Measuring, one of the specific skills tested (item 60), is that of selecting an appropriate unit for measuring the distance from the earth to the moon. The KR-20 coefficient of reliability for the whole test based on a norm group of suburban children is 0.91 [Tannenbaum, 1971].

The indices given in Table III-2 provide information on how the students performed on each item of the post-test. The *Difficulty Index* of an item is the proportion of students who got it right. Lindquist [1951] and Ebel [1965] recommend using items whose indices fall in the range 0.30 to 0.70. Items with indices in this range bring out more individual differences in performance than more

difficult or easier items. Table III-2 shows that only about one-half of the 96 items meet this criterion.

The *Discrimination Index* given for each item in Table III-2 is the point biserial correlation coefficient. The index provides information on the extent to which a given item discriminates among students who differ in their achievement of the science process skills as measured by the test as a whole. A point biserial r of 0.16 is statistically significant at the 0.05 level in the present case. Since the TOSP is fairly long (96 items), indices as low as 0.16 were considered satisfactory. Table III-2 shows that only 12 of the 96 items in the test had indices lower than 0.16. About one-half of the 96 items fulfilled both the difficult criterion and the discrimination criterion.

The results of the item analysis of the TOSP post-test given in Table III-2 were considered satisfactory for the purposes of the study and no further attempt was made to improve the items of the published form of the test used in the study or to delete the obviously poor items. Results, therefore, should be interpreted with caution.

With regard to validity of TOSP, Tannenbaum [1971, p. 123] states that "there is considerable evidence of both the content and the curricular validity of the test." In constructing a test which would assess students' abilities to use science processes regardless of particular science content, Tannenbaum prepared a blueprint of the test which specifically defined the science processes in behavioral

TABLE III-2

ITEM ANALYSIS OF TOSP (POST-TEST)

ITEM	DIFFICULTY INDEX	DISCRIMINATION INDEX	ITEM	DIFFICULTY INDEX	DISCRIMINATION INDEX
1	0.98	0.15	49	0.70	0.29
2	0.95	0.28	50	0.75	0.23
3	0.90	0.26	51	0.51	0.14
4	0.95	0.14	52	0.20	0.14
5	0.96	0.23	53	0.26	0.24
6	0.96	0.21	54	0.86	0.30
7	0.86	0.29	55	0.88	0.29
8	0.26	-0.04	56	0.78	0.51
9	0.95	0.21	57	0.62	0.48
10	0.90	0.17	58	0.63	0.41
11	0.96	0.22	59	0.75	0.36
12	0.38	0.10	60	0.53	0.18
13	0.81	0.18	61	0.83	0.33
14	0.89	0.29	62	0.54	0.46
15	0.59	0.35	63	0.72	0.54
16	0.61	0.11	64	0.76	0.55
17	0.75	0.35	65	0.53	0.30
18	0.72	0.44	66	0.57	0.25
19	0.60	0.34	67	0.52	0.14
20	0.47	0.19	68	0.61	0.31
21	0.59	0.21	69	0.44	0.29
22	0.89	0.38	70	0.42	0.16
23	0.59	0.19	71	0.65	0.52
24	0.95	0.18	72	0.65	0.47
25	0.98	0.33	73	0.38	0.31
26	0.91	0.44	74	0.65	0.25
27	0.90	0.33	75	0.78	0.41
28	0.70	0.16	76	0.71	0.12
29	0.78	0.12	77	0.75	0.23
30	0.96	0.33	78	0.34	0.07
31	0.81	0.19	79	0.60	0.29
32	0.78	0.46	80	0.50	0.36
33	0.74	0.36	81	0.30	0.32
34	0.81	0.24	82	0.92	0.29
35	0.62	0.50	83	0.52	0.30
36	0.89	0.40	84	0.29	0.08
37	0.41	0.34	85	0.48	0.42
38	0.76	0.29	86	0.37	0.23
39	0.92	0.27	87	0.70	0.36
40	0.85	0.16	88	0.81	0.56
41	0.97	0.32	89	0.44	0.35
42	0.61	0.42	90	0.41	0.24
43	0.95	0.15	91	0.74	0.20
44	0.80	0.44	92	0.70	0.35
45	0.86	0.34	93	0.54	0.06
46	0.87	0.16	94	0.45	0.33
47	0.71	0.27	95	0.39	0.26
48	0.86	0.37	96	0.70	0.11

terms [Tannenbaum, 1971, pp. 133-135]. This blueprint provided the guidelines for the preparation of the test items. Both the blueprint and the items were submitted to experts in science education who were requested to comment as to the clarity, appropriateness in the light of current science education, and difficulty with regard to the age-level (11 to 14 years).

Criterion-related validity was also investigated, where the criterion was the teacher-rating of the students' abilities to use the processes. A correlation coefficient of 0.48 for test scores versus teacher ratings was obtained. The size of this coefficient gives some support for criterion-related validity.

For the pre-test, the post-test, and the delayed post-test, the TOSP was administered separately to each of the classes in two sittings. In order to provide uniform testing conditions, the administration procedures specified in the Test Manual [Tannenbaum, 1971] were followed closely with one exception, the time limits specified were not imposed. An effort was made to ensure that students had ample time to complete the test. Students recorded their answers on special IBM answer cards used in data processing. Sample test items are contained in Appendix B.

3.0 EXPERIMENTAL PROCEDURES

3.1 Testing Phase

During the first week of the semester (September, 1972), the *Hidden Figures Test* was administered to all six classes separately.

In the second week the *Test of Science Processes* was given to all six classes separately as a pre-test. Test results were not analyzed until the end of the semester to ensure that the teachers involved in the study would not have any knowledge of the scores of individual students. During the last week of the semester (January, 1973), the TOSP was again administered as a post-test to all classes in the same manner as the pre-test. To provide a measure of retention of the science process skills learned, the TOSP was again administered at the end of April, 1973. A random sample of 36 students was selected from the original group of students by drawing two students from each of the three levels of cognitive style (global, middle, and analytic) from each class. The size of the sample was restricted to 36 due to administrative difficulties.

3.2 Teaching Phase

The teacher with the four classes (the author) randomly assigned two classes to each of the two teaching approaches (Labtext or ISC) described in Chapter II. The teacher with two classes randomly assigned one class to each approach. During the five months (September, 1972 to January, 1973) making up the first semester, classes were taught according to detailed lesson plans which were based on the following specifications for each method. The detailed lesson plans for each of the three units taught are contained in Appendix C.

(a) Specifications for the ISC Method of Teaching

Step 1 - The teacher discusses with the class the particular problem to be investigated. New vocabulary may be introduced, and previously learned concepts may be reviewed. The correct use of any necessary apparatus will be demonstrated.

Step 2 - Students perform the investigation by following the precise, written, step-by-step procedure. Students are guided in using the science processes by direct questions that accompany each step. These eliciting questions direct the inquiry in the desired direction. The teacher assists individual students during this time.

Step 3 - After students have completed the procedure, a class discussion will follow if necessary. Students then answer written questions for purposes of review, generalization, and application of results.

(b) Specifications for the Labtext Method of Teaching

Step 1 - The teacher discusses with the class the particular problem to be investigated. New vocabulary may be introduced, and previously learned concepts may be reviewed. The correct use of any necessary apparatus will be demonstrated.

Step 2 - The students read the outline of the investigation in the text and discussion of this may occur.

Step 3 - Whenever possible no written procedure is provided. (Occasionally the Labtext gives a specific procedure to follow when a difficult exercise is to be done.) Students are encouraged to develop their own procedure once they understand the purpose. At times students will be required to write down the series of steps they will perform. In this way a variety of procedures will be used throughout the class. If appropriate, students will make a prediction of expected results.

Step 4 - No written questions are provided to guide inquiry. Students follow their own procedures and list all their observations. The teacher assists individuals during this time, but encourages students to ask "yes/no" questions.

Step 5 - A class discussion follows and all observations are listed on the blackboard. Students compare these and classify those that are relevant to the problem.

Step 6 - By discussion, possible solutions to the problem are generated and these are compared with the predictions.

Step 7 - Discussion of the procedures follows, especially if conflicting results arise. Students will be asked to modify their procedure (if necessary) for a re-run of the experiment, and new predictions are made.

Step 8 - Students perform the re-run as suggested if appropriate.

Step 9 - Students answer written questions for purposes of review generalization, and application of results.

4.0 STATISTICAL PROCEDURES

4.1 Design of the Study

The experimental design used in the study was a 3 x 2 x 3 factorial design with one covariate. Factor 1, Cognitive Style, was broken down into three levels, Global, Middle, and Analytic. Factor 2, Methods, was subdivided into two levels, Labtext and ISC. Factor 3, Teacher, was subdivided into three levels representing three different teachers, T_1, T_2, and T_3. T_2 represents a replication of the study involving different classes but the same teacher (T_1). T_3 represents a second teacher. The criteria for classifying the subjects according to cognitive style were scores on the *Hidden Figures Test*. The range of scores for each group was set so that as close as possible to equal groups of students were contained within each level. Subjects with scores in the range 0-23 were classified as global. Scores ranging from 24-28 were used to identify the middle group, and subjects with scores in the range 29-32 were designated as the analytic group. Table III-3 summarizes the factors investigated and gives the number of subjects in each experimental group.

4.2 Statistical Hypotheses

The specific questions given in Chapter I were restated in the form of null hypotheses for testing purposes as follows:

I. Independent of teaching and methods, there will be no significant differences between mean scores on the TOSP of the global group, the middle group, and the analytic group.

TABLE III-3

THE DESIGN OF THE STUDY

TEACHER	TEACHING APPROACH	POST-TEST SCORES ON TOSP			TOTALS
		GLOBAL	MIDDLE	ANALYTICAL	
Teacher 1	ISC (Class 1)	7	6	14	27
	LABTEXT (Class 2)	12	5	8	25
Teacher 2	ISC (Class 3)	11	5	11	27
	LABTEXT (Class 4)	11	8	10	29
Teacher 3	ISC (Class 5)	10	7	9	26
	LABTEXT (Class 6)	8	9	9	26
TOTALS		59	40	61	160

II. There will be no significant differences between the mean scores on the TOSP of students in the Labtext classes and students in the ISC classes.

III. There will be no significant differences between the mean scores on the TOSP of students in classes with different teachers.

IV. There will be no interaction effect between teaching method and the cognitive style of the students.

V. There will be no interaction effect between teacher and the cognitive style of the students.

VI. There will be no interaction effect between teacher and teaching method.

VII. There will be no interaction effect between teacher, teaching method and the cognitive style of the students.

VIII. There will be no significant difference between mean scores on the delayed post-test and the post-test of a random sample of subjects used in the study.

Chapter IV presents a summary of the data obtained and an analysis of these data.

CHAPTER IV

ANALYSIS AND RESULTS

1.0 SUMMARY OF THE DATA

1.1 Summary of Hidden Figures Test Scores

The data given in Table IV-1 below was used to classify each student in one of the three categories of cognitive style, Global, Middle, and Analytic.

TABLE IV-1

SUMMARY OF HIDDEN FIGURES TEST SCORES

COGNITIVE STYLE GROUP	N	RANGE	MEAN SCORE	S.D.
Global	59	0-23	17.69	5.2214
Middle	40	24-28	26.28	1.4140
Analytic	61	29-32	30.84	1.1667

The table shows the range, mean score, and standard deviation for students within each level of cognitive style. The range of scores for each group was set so that as close as possible to equal groups of students were contained within each level.

1.2 Summary of TOSP Mean Scores for Pre-test and Post-test

Table IV-2 summarizes the TOSP pre-test mean scores, unadjusted TOSP post-test mean scores, adjusted TOSP post-test mean scores, and the sizes of the various groups investigated in the study.

The randomness of the sampling procedures used can be roughly evaluated by an inspection of the TOSP pre-test mean scores for each of the six classes in the last column of Table IV-2. The scores are quite close except in one case where they range from 58.7 to 64.0. This difference suggests the possibility that at least these two classes assigned to different methods of instruction differed significantly on past achievement of science process skills. Further, Table IV-2 reveals considerable variation in mean scores on the pre-test across and within each level of cognitive style. For example, mean scores for analytic students ranged from 59.5 in class 3 to 69.0 in class 2. In order to allow for these and other initial differences on achievement of science process skills prior to instruction, the TOSP post-test scores were adjusted by analysis of covariance in comparing group performance.

1.3 Summary of Delayed Post-test Scores

Table IV-3 contains the raw scores on the post-test and the delayed post-test for a sample of 36 students. This sample was obtained by randomly selecting two students from within each cell of the matrix shown in Table IV-2. The maximum possible score on the test was 96. Table IV-3 also shows the mean and standard deviation for each test.

TABLE IV-2

SUMMARY OF TOSP PRE-TEST AND POST-TEST SCORES

TEACHER (C)	METHOD (B)	COGNITIVE STYLE (A) (a_1) GLOBAL	(a_2) MIDDLE	(a_3) ANALYTIC	MEANS
T_1 (c_1)	(b_1) (class 1) ISC	55.6 63.7 68.5 7	62.2 68.8 68.4 6	63.0 70.7 69.7 14	60.9 68.5 68.9 27
	(b_2) (class 2) Labtext	57.1 64.9 68.5 12	66.2 74.4 70.9 5	69.0 75.1 69.4 8	62.7 70.1 69.6 25
T_2 (c_2)	(b_3) (class 3) ISC	55.4 58.8 63.7 11	64.2 62.0 60.0 5	59.5 66.1 67.8 11	58.7 62.4 63.9 27
	(b_2) (class 4 Labtext	59.5 62.2 63.8 11	64.8 68.5 66.1 8	68.2 72.6 67.5 10	64.0 67.5 65.8 29
T_3 (c_3)	(b_1) (class 5) ISC	54.4 56.7 62.4 10	59.1 66.1 68.1 7	65.8 68.9 65.7 9	59.6 63.5 65.4 26
	(b_2) (class 6) Labtext	55.0 61.5 66.7 8	63.6 66.4 65.0 9	67.6 73.6 69.0 9	62.3 67.4 66.9 26
	MEANS	56.3 61.3 65.6 59	63.2 67.6 66.4 40	65.1 70.9 68.2 61	61.4 66.6 66.7 160

KEY

TOSP pre-test mean → 55.6

Unadjusted TOSP post-test mean → 63.7

Adjusted TOSP post-test mean → 68.5

Cell size (N) → 7

Cell Entries in Table IV-2

Table IV-3 reveals that the mean scores for the groups on each test are quite close, indicating that the group as a whole has shown no marked change in performance over the period of three months during which no science instruction was given. A closer inspection reveals that individuals show some marked changes. Six students have shown a decrease of greater than five points on the delayed post-test, while nine other students have shown an increase of greater than five. These results are analyzed statistically in Section 2.0.

2.0 ANALYSIS OF THE DATA

2.1 Statistical Hypotheses

The statistical hypotheses, as given in Chapter III, and corresponding to the specific questions stated in Chapter I, are restated below as null hypotheses to be tested.

Main Effects:

1. H_0: $\Sigma\alpha_h^2 = 0$, Cognitive style (A) has no significant effect.
2. H_0: $\Sigma\beta_i^2 = 0$, Method of instruction (B) has no significant effect.
3. H_0: $\Sigma\gamma_j^2 = 0$, Teachers (C) have no significant effect.

Interaction Effects:

4. H_0: $\Sigma(\alpha\beta_{hi})^2 = 0$, No significant AB interaction effect.
5. H_0: $\Sigma(\alpha\gamma_{hj})^2 = 0$, No significant AC interaction effect.
6. H_0: $\Sigma(\beta\gamma_{ij})^2 = 0$, No significant BC interaction effect.
7. H_0: $\Sigma(\alpha\beta\gamma_{hij})^2 = 0$, No significant ABC interaction effect.

TABLE IV-3

POST-TEST AND DELAYED POST-TEST RAW SCORES

STUDENT NUMBER	POST-TEST	DELAYED POST-TEST
1	75	76
2	77	76
3	86	81
4	73	74
5	67	59
6	78	83
7	73	78
8	76	74
9	81	81
10	72	63
11	77	83
12	74	68
13	42	58
14	67	78
15	77	65
16	75	74
17	66	75
18	77	84
19	84	86
20	76	74
21	76	71
22	68	72
23	78	81
24	71	60
25	68	65
26	72	67
27	88	88
28	53	67
29	78	78
30	62	64
31	56	63
32	60	79
33	54	57
34	62	71
35	69	74
36	67	58
	MEAN 70.97	MEAN 72.36
	S.D. 9.64	S.D. 8.64

Delayed Post-test:

8. H_0: $\mu_1 = \mu_2$, No significant difference on delayed post-test compared to post-test.

2.2 Summary of Analysis of Variance on Adjusted TOSP Post-test Mean Scores

In order to determine whether the various group differences on the TOSP pre-test (covariate) suffice to account for differences on the TOSP post-test (criterion), or whether the differences on the criterion are due to different methods of instruction (treatments) or teachers, an analysis of variance on the adjusted post-test scores was carried out. The results are summarized in Table IV-4 below.

TABLE IV-4

ANALYSIS OF VARIANCE ON ADJUSTED TOSP POST-TEST SCORES

SOURCE OF VARIATION	SUM OF SQUARES	D.F.	MEAN SQUARES	F	p
A: Cognitive Style	206.4	2	103.2	2.48*	<0.0872
B: Method	39.7	1	39.7	0.96	<0.3298
C: Teacher	464.4	2	232.2	5.59**	<0.0047
AB: Cog. Style X Method	2.2	2	1.1	0.03	<0.9721
AC: Cog. Style X Teacher	81.6	4	20.4	0.49	<0.7429
BC: Method X Teacher	6.8	2	3.4	0.08	<0.9217
ABC: Cog. Style X Method X Teacher	235.6	4	58.9	1.42***	<0.2316
Error:	5865.6	141	41.6		

Key to Table IV-4

*Significant at = 0.10 level

**Significant at = 0.05 level

***Significant at = 0.25 level

2.3 Tests of Statistical Hypotheses

Table IV-4 indicates that for factors A and C, significant F-ratios were obtained, leading to the rejection of null hypotheses 1 and 3. The table also shows that the three-factor interaction effect, ABC, (null hypothesis 7) approaches conventional levels of statistical significance.

1. Main Effects:

The A (Cognitive Style) mean square corresponds to a comparison of the adjusted means for the three different cognitive styles averaged over the two levels of B (Method) and three levels of C (Teacher). The adjusted means on the TOSP for the three levels of A are given in Table IV-2 and are reproduced here for convenience:

a_1 (Global)..... 65.6

a_2 (Middle)..... 66.4

a_3 (Analytic)..... 68.2

The fact that the A mean square is significant implies that the three adjusted means differ significantly. In order to establish which means are significantly different, 90% confidence intervals were constructed around estimates of contrasts between the means

according to the S-method [Glass and Stanley, 1970, p. 393]. The results are given in Table IV-5 below.

TABLE IV-5

SUMMARY OF CONTRASTS

$(\mu_{a_i} - \mu_{a_{i'}})$

	μ_{a_1}	μ_{a_2}	μ_{a_3}
μ_{a_1}		0.8	2.6*
μ_{a_2}			1.8
μ_{a_3}			

*Significant at 0.10 level.

The table shows that only the contrast between the global and analytic students is significant at the 0.10 level and contributes to the overall significance of factor A. The achievement of the analytic group was significantly superior to the global group.

The factor C (Teacher) mean square represents a comparison between means of classes designated as being taught by Teacher 1 (c_1), Teacher 2 (c_2), and Teacher 3 (c_3), averaged over the three levels of A and two levels of B. The adjusted means for these three groups are as follows:

c_1 (Teacher 1) 69.2
c_2 (Teacher 2) 64.8
c_3 (Teacher 3) 66.1

Table IV-6 gives a summary of contrasts between the adjusted means of students taught by the three teachers.

TABLE IV-6

SUMMARY OF CONTRASTS

$(\mu_{c_j} - \mu_{c_{j'}})$

	μ_{c_1}	μ_{c_2}	μ_{c_3}
μ_{c_1}		4.4*	3.1*
μ_{c_2}			1.3
μ_{c_3}			

*Significant at 0.05 level.

The table shows that the contrasts between some of the classes designated as having been taught by T_1, T_2, and T_3 are significant at the 0.05 level and contributed to the overall significance of factor C.

The two teachers designated as Teacher 1 and 2 were actually one and the same person, i.e., the investigator in the present study. The original intent was to use the two classes designated as having been taught by Teacher 2 for replicating the teaching performance involving the classes designated as having been taught by Teacher 1. As it turned out, the order in which the classes were taught did not remain the same. As a consequence, only two levels of factor C actually existed, namely, level $c_1 + c_2$ and level c_3.

In order to determine whether the combined achievement of students designated as having been taught by T_1 and T_2 differed significantly from the achievement of Teacher 3's students, a 95% confidence interval was constructed for estimates of the contrast $\mu_{c_3} - 1/2(\mu_{c_1} + \mu_{c_2})$, i.e., $\bar{X}_{c_3} - 1/2(\bar{X}_{c_1} + \bar{X}_{c_2})$, using the S-method. the results are given below:

Estimates of contrasts:	0.9
95% confidence interval:	(-3.6, 1.8)

The fact that the confidence interval spans 0 implies that the combined achievement of the writer's students did not contribute to the significance of the F-ratio of factor C. The overall significance of the factor, then, was due to unidentified differences between some of the classes taught by the writer and not necessarily due to a Teacher effect.

2. Interaction Effects:

Table IV-4 shows that the three-factor interaction mean square is significant at the 0.25 level. This result suggests that qualified statements about the effects of teachers, methods, and cognitive style could be made. In order to determine what qualifications to make, a graphical analysis of the data summarized for this purpose in Table IV-7 was carried out.

TABLE IV-7

DATA FOR GRAPHICAL ANALYSIS OF INTERACTION EFFECTS

(i)

	c_1 and c_2 (Teachers 1+2)		
	b_1 (ISC)	b_2 (LAB)	MEAN
a_1 (Global)	66.08	66.15	66.12
a_2 (Middle)	64.23	68.48	66.36
a_3 (Analytic)	68.74	68.47	68.60
MEAN	66.35	67.70	67.02

(ii)

	c_3 (Teacher 3)		
	b_1 (ISC)	b_2 (LAB)	MEAN
a_1	62.35	66.68	64.52
a_2	68.10	64.97	66.54
a_3	65.69	68.97	67.33
MEAN	65.38	66.88	66.13

(iii)

	Combined c's (Overall AB)		
	b_1 (ISC)	b_2 (LAB)	MEAN
a_1	64.84	66.33	65.59
a_2	65.53	67.32	66.42
a_3	67.73	68.64	68.18
MEAN	66.03	67.43	66.73

Figure 1 (i, ii) shows that the non-zero ABC interactions were not the same over all levels of C (Teachers). According to Figure 1, the Labtext method (b_2) is superior to the ISC approach (b_1) only for

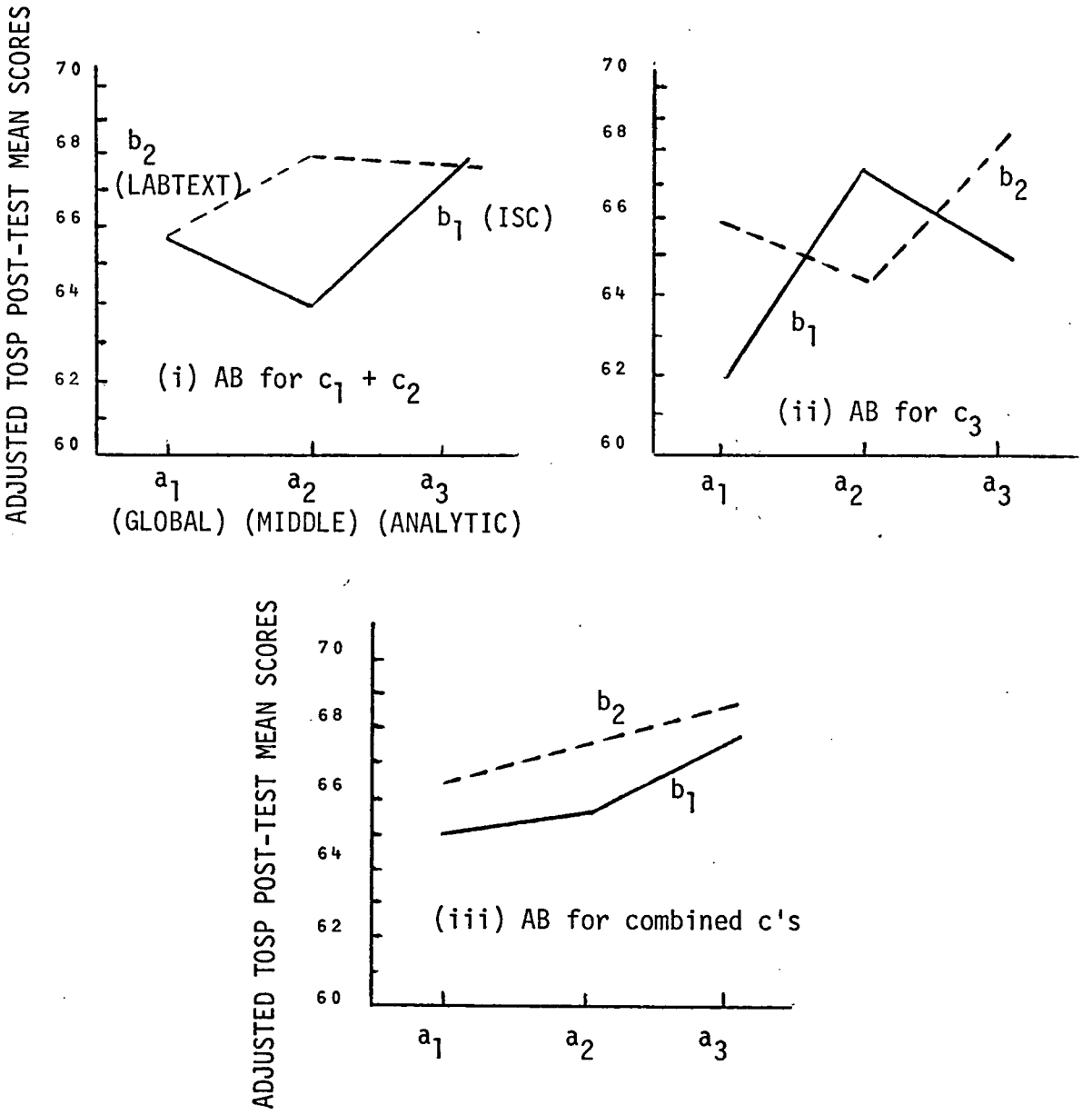


Figure 1 Interaction of cognitive style (A) and method (B) for levels of teachers (C).

the middle cognitive style groups (a_2) as taught by the writer. In the case of Teacher 3, the Labtext method (b_2) is superior to the ISC approach (b_1) for both the global (a_1) and analytic (a_3) groups of students. The superiority of the ISC approach for the middle group (a_2) is opposite to that obtained by the writer (c_1 and c_2). These results indicate that the superiority of the Labtext method over the ISC method depends on the cognitive style of the learners and, evidently, on the teacher as well.

3. Delayed Post-test Results:

For convenience the means given in Table IV-3 for the post-test and the delayed post-test for a sample of 36 students are reproduced as follows:

Post-test 70.97

Delayed Post-test 72.36

A correlated t-test between the scores shown in Table IV-3 yielded a t-value of 1.13 which is not significant at the 0.10 level. On the basis of this result, null hypothesis 8, that there is no significant difference between the scores on the post-test and the scores on the delayed post-test for a random sample of 36 students, was accepted.

3.0 SUMMARY OF RESULTS

The results of this study can best be summarized as answers to the specific questions stated in Chapter I.

1. Independent of the teacher or teaching method, the achievement of analytic students was superior to that of global students.
2. Independent of the teacher and the cognitive style of the students, neither method of teaching resulted in a higher level of achievement in science process skills.
3. Independent of cognitive style and method, the results indicated that the two teachers attained comparable results with respect to achievement of science process skills. The combined achievement of Teacher 1 and Teacher 2 students was found to be not significantly different to the achievement of students of Teacher 3.
4. There was no interaction effect between the teaching method and the cognitive style of the students.
5. There was no interaction effect between the teacher and the cognitive style of the students.
6. There was no interaction effect between teacher, teaching method, and the cognitive style of the students. For students taught by Teacher 1 and Teacher 2, the Labtext method was superior to the ISC method only for the middle cognitive style groups. For students taught by Teacher 3, the Labtext approach was superior to the ISC approach for both global and analytic students, while the ISC method was superior to the Labtext method for middle students.

7. There was no statistically significant difference between the mean post-test score and the mean delayed post-test score for a sample of 36 students three months after termination of science instruction.

CHAPTER V

CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

1.0 CONCLUSIONS

This investigation grew out of the author's classroom teaching experience. It was observed that in classes of grade 8 students using "*Labtext in Science, Book 1*" [Cannon et al., 1968] as a guide, some students seemed to experience difficulty in performing the investigations while certain other students found these investigations to be exciting and rewarding. Similar observations were made in classes using the text "*Introducing Science Concepts in the Laboratory*" [Schmid, 1971]. The different learning styles appeared to have no relation to the "intelligence" of students as measured by standard IQ tests. Some students in both classes who experienced difficulty possessed a relatively high IQ.

The writer sensed that Witkin's concept of Field Dependence [Witkin et al., 1962] could be a useful way of explaining why one method of science instruction could suit the learning style of some students and not others. In order to investigate this notion more systematically, two methods of teaching embodied in the two different texts identified above were, first of all, carefully delineated. Briefly, the Labtext method was described as a learning situation which allowed much freedom of individual action during an investigation, while the ISC method was described as a structured learning situation

in which specific instructions were given and guiding questions were asked. On the basis of Witkin's findings [Witkin, 1969] it was felt that field dependent (global) students would function better with the ISC method while field independent (analytic) students would be more successful with the Labtext approach. Cognitive style was assessed by means of the *Hidden Figures Test*, and achievement was measured by means of the *Test of Science Processes*.

The experimental phase of this study took place over a period of one complete school semester. At the outset students were randomly assigned to six classes of which the author taught four, with two classes assigned randomly to each method. A second teacher taught two classes, randomly assigning one class to each method. The involvement of two different teachers allowed a study of the effect of teachers on achievement, and the fact that one teacher taught two classes with each method provided a situation in which the effect of one teacher using the same methods with different classes could be studied.

It was hoped that the results of this investigation would suggest answers to two basic questions, namely, (1) Is the mental factor of Field Dependence a significant predictor of achievement of science process skills? and (2) To which of the three different levels of Field Dependence, global, middle, or analytic are the two major methods of teaching Science 8 in British Columbia schools (ISC, Labtext), best suited?

1.1 Effect of Cognitive Style

A clear-cut answer to the first question was obtained. Analytic students scored significantly higher than the global students on the criterion measure, the TOSP post-test. This result is not surprising in the light of several factors. The analytical nature of science can be expected to favour analytic students and indeed research has shown that these students do favour science in terms of academic and vocational preference [Chung, 1966; DeRussy and Futch, 1971]. Messick [1970] also points out that test formats and test conditions, such as those used in this study, may favour analytic students.

1.2 Effect of Method

Since no evidence of overall superiority of one method of instruction over the other was obtained, no simple answer can be given to the second question. The evidence suggests that in order to answer the question of which method is best suited to a particular cognitive style, the teacher must also be taken into account. It may be, as suggested later in this chapter, that the cognitive style of the teacher is the operative variable in this regard.

1.3 Effect of Teacher

The evidence obtained indicates that there was no overall superiority in the achievement of science process skills of students taught by one teacher or the other. Replication of the study, in which

the writer taught four different classes using the two different methods did, however, produce significant differences between the mean scores of some of his own classes. This finding suggests that, overall, the inter-teacher effects can be as great or greater than the intra-teacher effects. Although the analysis of main effects made it impossible to claim overall superiority of the students of any particular teacher, analysis of interaction effects suggested that a qualified statement about teacher effects could be made. Further discussion of this point is given in the next section.

1.4 Interaction of Teacher, Method and Cognitive Style

No significant interaction effect was found between any two of the Teacher, Method, or Cognitive Style factors. However, the three-way interaction between these factors did approach a level of statistical significance which suggested the need for analysis. A general conclusion is extremely difficult to formulate because of the nature of the interaction and the many intervening variables. However, graphical analysis suggests that the effectiveness of a teaching method for a particular cognitive style does depend on the teacher. For one teacher the Labtext method appears superior to the ISC method only for the middle cognitive style groups. For the other teacher, the Labtext method was superior to the ISC approach for both global and analytic students while the ISC approach was superior to the Labtext approach for the middle students. In effect, the teachers obtained almost opposite results.

1.5 Delayed Post-test

No significant difference was found between the scores of 36 randomly selected students on the post-test and the scores on the delayed post-test. From this result it can be concluded that these students retained the knowledge of science processes over the period of three months during which no science instruction was given. Regrettably, the delayed post-test could not be given to all the students involved in the study because of administrative problems within the school. There was an interesting slight trend towards higher scores on the delayed post-test, which may have been a consequence of one or more factors such as maturation (which was not controlled in this study), chance, or test unreliability.

One factor which could have had a significant effect on the outcome of this study was the factorial design used. Analysis of regression, Walberg [1971] points out, is the preferred method of analysis because the error component due to artificial cutoffs of a continuous variable (cognitive style) is reduced. Another factor which may have affected the results is the cognitive style of the teacher. This possibility is discussed in Section 2.0.

As previously noted in Chapter III, item analysis of the TOSP post-test revealed a lack of precision in the measuring instrument. Only one-half of the 96 items fulfilled the difficulty criterion and the discrimination criterion. Results should therefore be interpreted accordingly and researchers contemplating using this test in the future should check the operational characteristics carefully.

2.0 IMPLICATIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

This study has shown that the cognitive style of students is directly related to achievement in science process skills at the grade eight level. There is sufficient evidence to justify the development of further studies to determine the effect of cognitive style on other measures such as attitude, and the learning of scientific facts and principles at all grade levels. Furthermore, in this investigation only two methods of teaching were studied and other methods may be developed which will be better suited to students with different cognitive styles.

The concept of cognitive style offers several possibilities for education but many of these depend upon the results of much needed research. A problem in this area is that the very pervasiveness of cognitive styles among people interferes with evaluation techniques which attempt to assess the effect of controlled educational variables. Research is necessary to discover whether test formats tend to favour one particular cognitive style group.

This study has provided evidence that the effectiveness of a particular teaching method for particular cognitive style groups depends on the teacher. It may be that the teacher's own cognitive style is the variable which is responsible for this dependency. The effect of a match or mismatch of the teacher's cognitive style with that of students was investigated by DiStefano [1969]. However, only attitudes were measured. Research that showed superior achievement in classes where teachers and students were matched for cognitive style would

prove invaluable for investigating the effect of different teaching methods on cognitive style.

A promising possibility for future education, implied in the preceding paragraph, is the homogeneous grouping of students on the basis of cognitive style. Many educators today are vigorously opposed to homogeneous grouping on the basis of so-called "intelligence" because of the stigma attached to students in the lower ability classes. By means of group tests, students can easily be placed in classes according to cognitive style, and it is unlikely that detrimental labels will be attached to such classes since Witkin et al., [1962] has shown that a global student has as much chance as an analytic student of scoring high on standard IQ and verbal ability tests. As yet, it is by no means clear that such placement of students will foster learning, but alternatively, as pointed out by Messick [1970, p. 197], "it is by no means clear that homogeneous ability grouping is uniformly beneficial." Research in this area should provide many valuable answers to this problem.

Witkin and his associates [1962] have amassed considerable evidence regarding the stability of an individual's cognitive style. Messick [1970] suggests the possibility of developing the ability of a student to make "a conscious choice among alternative modes of perceiving, remembering, thinking, and problem solving as a function of the conditions of particular situations" [Messick, 1970, p. 198]. In effect, what is recommended is that research aim at determining the age at which cognitive styles become immutable if, in fact, they

do. Furthermore, researchers should attempt to determine the degree to which cognitive styles are malleable before a particular style becomes predominant.

The importance of cognitive styles not only in the field of education, but in life itself has been appropriately described by Messick:

> Cognitive styles, by embracing both perceptual and intellectual domains and by their frequent implication in personality and social functioning, promise to provide a more complete and effective characterization of the student than could be obtained from intellectual tests alone. . . . These stylistic characteristics should have relevance . . . not only for the course of individual learning in various subject matter areas, but also for the nature of teacher-pupil interactions and of social behavior in the classroom, the family, and the peer group. [Messick, 1970, pp. 195-196]

REFERENCES

American Association for the Advancement of Science, 1968. Science -- A Process Approach, Parts 1 to 7 (A and B). Miscellaneous Publications.

Belanger, Maurice, 1969. Learning studies in Science education. Review of Educational Research, 39, 377-395.

Bell, D.R., 1964. The relationship between reward and punishment-avoidance orientations and selected perceptual variables. Unpublished doctoral dissertation, University of Oregon.

Berry, J.W., 1966. Temne and Eskimo perceptual skills. International Journal of Psychology, 1, 207-229.

Bloom, B.S., 1956. Taxonomy of Educational Objectives, Handbook 1: Cognitive Domain. New York: David McKay Co., Inc.

Brown, Walter R., 1968. Defining the processes of science. The Science Teacher, 35, 26-28. (December)

Burns, Richard W., and Brooks, Gary D., 1970. What are educational Processes? The Science Teacher, 37, 27-28. (February)

Buros, Oscar K., 1972. The Seventh Mental Measurements Yearbook. New Jersey: Gryphon Press, p. 440.

Cannon, G.H. et al., 1968. Labtext in Science, Book 1. Vancouver: Copp Clark.

Carleton, Robert H., 1967. Science education in the middle or junior high school grades. The Science Teacher, 34, 25-28. (December)

Chung, W-S., 1967. Relationships among measures of cognitive style, vocational preferences, and vocational identification. Unpublished doctoral dissertation, George Peabody College for Teachers.

Cohen, J., 1957. The factorial structure of the W.A.I.S. between early adulthood and old age. Journal of Consulting Psychology, 21, 283-290.

Cohen, J., 1959. The factorial structure of the W.I.S.C. at ages 7-6, 10-6, and 13-6. Journal of Consulting Psychology, 23, 8-59.

Cronbach, Lee, J., 1964. Learning research and curriculum development. Journal of Research in Science Teaching, 2, 204-207.

Cronbach, Lee J., 1967. How can instruction be adapted to individual differences? In R.M. Gagné's (ed.) Learning and Individual Differences. Columbus, Ohio: Merrill Books.

Dawson, J.L.M., 1967. Cultural and physiological influence upon spatial-perceptual processes in West Africa - Parts I and II. International Journal of Psychology, 2, 115-128; 171-185.

Deever, S.G., 1967. Ratings of task-oriented expectancy for success as a function of internal control and field independence. Unpublished doctoral dissertation, University of Florida.

DeRussy, E.A., and Futch, E., 1971. Field dependence-independence as related to college curricula. Perceptual and Motor Skills, 33, 1235-1237.

DiStefano, J.J., 1969. Interpersonal perceptions of field independent teachers and students. Unpublished doctoral dissertation, Cornell University.

Dyk, R.B., 1969. An exploratory study of mother-child interaction in infancy as related to the development of differentiation. Journal of the American Academy of Child Psychiatry, 8, 657-691.

Dyk, R.B., and Witkin, H.A., 1965. Family experiences related to the development of differentiation in children. Child Development, 30, 21-55.

Ebel, R.L., 1965. Measuring Educational Achievement. New Jersey: Prentice-Hall.

Elashoff, Janet D., 1969. Analysis of covariance: A delicate instrument. American Educational Research Journal, 6(3), 383-402.

Faterson, H.F., and Witkin, H.A., 1970. Longitudinal study of development of the body concept. Developmental Psychology, 2(3), 429-438.

Fish, Alphoretta S., and Goldmark, Bernice, 1969. Inquiry method: Three interpretations. In Readings in Science Education for the Secondary School, Hans O. Andersen (ed.). New York, Macmillan.

Fitz, R.J., 1970. The differential effects of praise and censure on serial learning as dependent on locus of control and field dependency. Unpublished doctoral dissertation, Catholic University of America.

Gagné, Robert M., 1963(a). A psychologist's counsel on curriculum design. Journal of Research in Science Teaching, 1, 27-32.

Gagné, Robert M., 1963(b). The learning requirements for enquiry. Journal of Research in Science Teaching, 1, 144-153.

Gagné, Robert M., 1970. The Conditions of Learning. New York: Holt, Rinehart and Winston.

Glass, Gene V., and Stanley, Julian C., 1970. Statistical Methods in Education and Psychology. New Jersey: Prentice-Hall, Inc.

Glatt, C.J.W., 1969. The relationship of level of differentiation, acceptance of authority and locus of control to readiness for vocational planning in eighth grade boys. Unpublished doctoral dissertation, New York University.

Goodenough, D.R., and Eagle, C.J., 1963. A modification of the embedded-figures test for use with young children. Journal of Genetic Psychology, 103, 67-74.

Goodenough, D.R., and Karp, S.A., 1961. Field dependence and intellectual functioning, Journal of Abnormal and Social Psychology, 63, 241-246.

Grieve, T.D., and Davis, J.K., 1971. The relationship of cognitive style and method of instruction to performance in ninth grade geography. Journal of Educational Research, 65, 137-141.

Jackson, Douglas N., Messick, Samuel, and Myers, Charles T., 1964. Evaluation of group and individual forms of embedded figures measures of field independence. Educational and Psychological Measurement, 24(2), 177-192.

Joyce, Bruce and Weil, Marsha, 1972. Models of Teaching. Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Karp, S.A., 1963. Field dependence and overcoming embeddedness. Journal of Consulting Psychology, 27, 294-302.

Keogh, B.K., and Donlon, G. McG., 1972. Field dependence, impulsivity, and learning disabilities. Journal of Learning Disabilities, 5, 16-21.

Klopfer, Leopold E., 1971. Evaluation of learning in science In Bloom, B.S., Hastings, J.T., and Madaus, G.F., Handbook on Formative and Summative Evaluation of Student Learning. New York: McGraw-Hill, 559-641.

Konstadt, N., and Forman, E., 1965. Field dependence and external directedness. Journal of Personality and Social Psychology, 1, 490-493.

Lindquist, E.F. (ed.), 1951. Educational Measurement. Washington, D.C.: American Council on Education.

Livermore, Arthur H., 1964. The process approach of the AAAS Commission on science education. Journal of Research in Science Teaching, 2, 271-282.

Messick, Samuel, 1970. The criterion problem in the evaluation of instruction. In The Evaluation of Instruction, M.C. Wittrock and David E. Wiley, (eds.). Toronto: Holt, Rinehart and Winston, Inc., Chapter 6.

McAnarney, Harry, 1972. What is the place of product and process in the development of generalizations in elementary schools science? Science Education, 56, 85-88.

Mitchell, James V. Jnr., 1969. Education's challenge to psychology: The prediction of behavior from person-environment interactions. Review of Educational Research, 39, 695-721.

Nay, Marshall A., and Associates, 1971. A process approach to teaching science. Science Education. 55(2), 197-207.

Neisser, Ulric, 1966. Cognitive Psychology. New York: Appleton-Century-Crofts.

NSTA Committee on Curriculum Studies: K-12, 1971. NSTA position statement on school science education for the seventies. The Science Teacher, 38, 46-51. (November)

Nunnally, Jum C., 1967. Psychometric Theory. New York: McGraw Hill Book Company.

Paclisanu, M.I., 1969. Interacting effects of stimulus deprivation, field dependence and two types of reinforcement upon problem-solving in elementary school children. Unpublished doctoral dissertation, Temple University.

Pierson, J.S., 1965. Cognitive styles and measured vocational interests of college men. Unpublished doctoral dissertation, University of Texas.

Junior Secondary School Science, Science 8, 1968. Province of British Columbia, Department of Education, Division of Curriculum, Victoria.

Rainey, Robert G., 1965. The effects of directed versus non-directed laboratory work on high school chemistry achievement. Journal of Research in Science Teaching, 3, 286-292.

Ramsey, G.A., and Howe, R.W., 1969(a). An analysis of research on instructional procedures in secondary school science, part I - outcomes of instruction. The Science Teacher, March, 62-70.

Ramsey, G.A., and Howe, R.W., 1969(b). An analysis of research on instructional procedures in secondary school science, part II - instructional procedures. The Science Teacher, April, 72-81.

Randolph, L.C., 1971. A study of the effects of praise, criticism and failure on the problem solving performance of field dependent and field independent individuals. Unpublished doctoral dissertation, New York University.

Robbins, H., 1962. Field articulation: Its relationship to reading disability and social class. Unpublished doctoral dissertation, New York University.

Ruble, D.N., and Nakamura, C.Y., 1972. Task orientation versus social orientation in young children and their attention to relevant social cues. Child Development, 43, 471-480.

Rummel, J. Francis, 1958. An Introduction to Research Procedures in Education. New York: Harper & Brothers.

Rutherford, F. James, 1964. The role of inquiry in science teaching. Journal of Research in Science Teaching, 2, 80-84.

Salomon, Gavriel, 1972. Heuristic models for the generation of aptitude-treatment interaction hypotheses. Review of Educational Research, 42(3), 327-343.

Schmid, Manfred I., (ed.), 1972-73. Introducing Science Concepts in the Laboratory. Vancouver: Science Teachers' Association of the B.C. Teachers' Federation.

Schwartz, D., and Karp, S.A., 1967. Field dependence in a geriatric population. Perceptual and Motor Skills. 24, 495-504.

Sears, Paul B. and Kessen, William, 1964. Statement of purposes and objectives of science education in schools. Journal of Research in Science Teaching, 2, 3-6.

Sieben, Gerald A., 1971. Cognitive Style and Children's Performance on Measures of Elementary Science Competencies. Unpublished Master's Thesis, University of British Columbia, Vancouver.

Smith, H.A., 1963. Educational research related to science instruction for the elementary and junior high school: A review and commentary. Journal of Research in Science Teaching, 1, 199-225.

Spitler, G., 1970. An investigation of various cognitive styles and the implications for mathematics education. Unpublished doctoral dissertation, Wayne State University.

Suchman, J. Richard, 1964. The Illinois studies in inquiry training. Journal of Research in Science Teaching, 2, 231-232.

Suchman, J. Richard, 1966(a). A model for the analysis of inquiry. In Analysis of Concept Learning, Herbert J. Klausmeier and Chester W. Harris (eds.). New York: Academic Press.

Suchman, J. Richard, 1966(b). Inquiry Development Program: Developing Inquiry. Chicago: Science Research Associates.

Suchman, J. Richard, 1966(c). Inquiry Development Program in Physical Science: Teacher's Guide. Chicago: Science Research Associates.

Taba, Hilda, 1966. Teaching Strategies and Cognitive Functioning in Elementary School Children. San Francisco State College, Cooperative Research Project No. 2404.

Taba, Hilda, 1967. Teacher's Handbook for Elementary Social Studies. Reading, Mass.: Addison-Wesley.

Tannenbaum, Robert S., 1971. Development of the test of science processes. Journal of Research in Science Teaching, 8, 123-136.

Tyler, Leona E., 1965. The Psychology of Human Differences. New York: Appleton-Century-Crofts.

Tyler, Ralph W., 1968. Resources, models, and theory in the improvement of research in science education. Journal of Research in Science Teaching, 5, 43-51.

Walbesser, Henry H., 1963. Curriculum evaluation by means of behavioral objectives. Journal of Research in Science Teaching, 1, 296-301.

Walberg, Herbert J., 1971. Generalized regression models in educational research. American Educational Research Journal, 8, p. 75.

Ward, Joe H. Jnr., and Howe, Anne, 1971. Comparing instructional objectives in the presence of a concomitant variable. Science Education, 55, 227-231.

Welch, Wayne and Pella, Milton O., 1968. The development of an instrument for inventorying the processes of science. Journal of Research in Science Teaching, 8, 64-68.

White, B.O., and Kernaleguen,A.P., 1971. Comparison of selected perceptual and personality variables among college women deviant and nondeviant in their appearance. Perceptual Motor Skills, 32, 87-92.

Winer, B.J., 1971. Statistical Principles in Experimental Design. Toronto: McGraw-Hill Book Company.

Witkin, Herman A., 1950. Individual differences in ease of perception of embedded figures. Journal of Personality, 19, 1-15.

Witkin, Herman A., 1967. A cognitive-style approach to cross-cultural research, International Journal of Psychology, 2(4), 233-250.

Witkin, Herman A., 1969. Implications of research on cognitive style for problems of education. Professional School Psychology, 3, 198-227.

Witkin, Herman A., 1972. The role of cognitive style in academic performance and in teacher-student relations. Paper presented at a symposium on "Cognitive Styles, Creativity and Higher Education," sponsored by the Graduate Record Examination Board, Montreal.

Witkin, H.A., Dyk, R.B., Faterson, H.F., Goodenough, D.R. and Karp, S.A., 1962. Psychological Differentiation. New York: John Wiley & Sons.

Witkin, H.A., Faterson, H.F., Goodenough, D.R., and Birnbaum, Judith, 1966. Cognitive patterning in mildly retarded boys. Child Development, 37, 301-316.

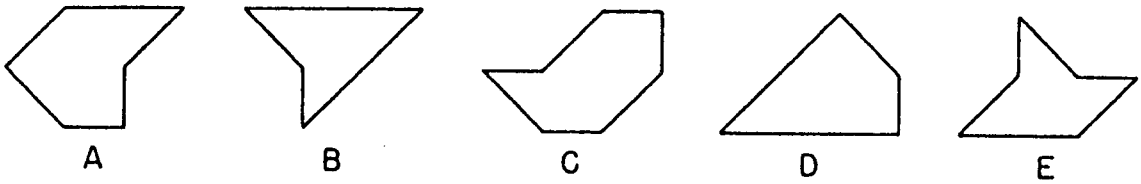
Witkin, H.A., Goodenough, D.R., and Karp, S.A., 1967. Stability of cognitive style from childhood to young adulthood. Journal of Personality and Social Psychology, 7, 291-300.

Witkin, H.A., Lewis, Helen B., Hertzman, M., Machover, Karen, Meissner, Pearl B., and Wapner, S., 1954. Personality Through Perception. New York: Harper.

APPENDIX A

SAMPLE ITEMS FROM THE HIDDEN FIGURES TEST

Part 2 (continued)



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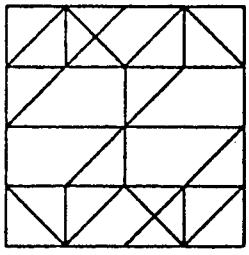

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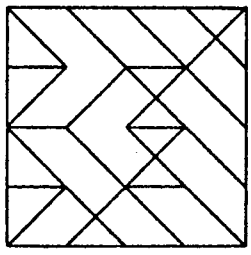

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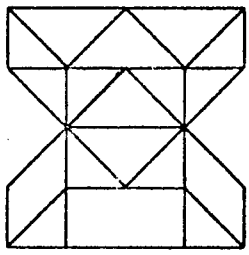

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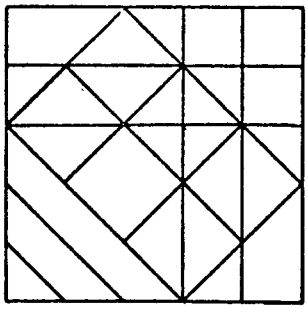

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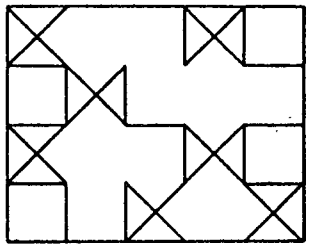

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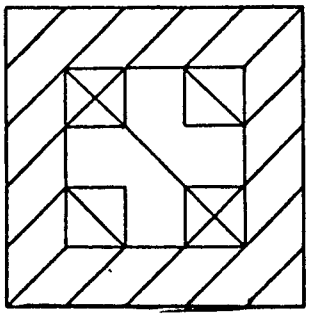

A B C D E

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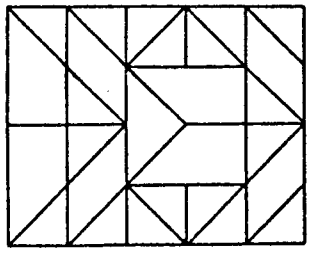

A B C D E

APPENDIX B

SAMPLE ITEMS FROM THE TEST OF SCIENCE PROCESSES

Science Process Skill: Quantifying

32. Which one of these temperature readings is 25 degrees *lower* than 15°F?

    1. -10°F
    2. 15°F
    3. -25°F
    4. 0°F
    5. 40°F

35. Which one of these decimals is equal to 15/100?

    1. .0015
    2. .015
    3. 15.0
    4. 1.5
    5. .15

Science Process Skill: Measuring

46. Which one of these units would be best suited for use in measuring the weight of a loaded freight car?

    1. Pounds
    2. Liters
    3. Tons
    4. Kilograms
    5. Grams

60. Which one of these units would be best to use in measuring the distance from the earth to the moon?

    1. Yards
    2. Feet
    3. Inches
    4. Miles
    5. Light Years

Science Process Skill: Inferring

94. In order to prove that "*NOT* ALL THINGS GET BIGGER AS YOU HEAT THEM," which of the following would you need to do?

    1. Find one thing that does not get bigger when it is heated.
    2. Find all the things that do not get bigger when they are heated.
    3. Find one thing that gets bigger when it is heated.
    4. Find all the things that get bigger when they are heated.
    5. Find all the things that do not change size when they are heated.

APPENDIX C

DETAILED LESSON PLANS FOR THE CHEMISTRY, BIOLOGY, AND OPTICS UNITS, USING THE LABTEXT METHOD AND THE ISC METHOD

CHEMISTRY UNIT

Introducing Science Concepts in the Laboratory (Method 1)

Period 1 - Unit I: Chemistry: The Study of Matter.

Begin Expt. I-1. (page 4)

Purpose: Just for fun, to mix 3 chemicals and see what happens.

Step 1. (a) Define chemistry as a study of matter. List different materials and classify as man-made or natural.

(b) Define the purpose of this experiment.

Step 2. (a) Students follow procedures 1 to 4.

Step 3. (a) Students answer questions 1 to 3 (page 5).

Period 2 -Step 2. (b) Complete procedure 4 of Expt. I-1.

Step 3. (b) Discuss answers to questions 1 to 3.

Begin Expt. I-2. (page 5)

Purpose: To use indicators to group materials.

Step 1. (a) Show how to use graduated cylinders to measure volume (see also page 200).

(b) Lead from step 3(b) above which shows the need for measuring, to define the purpose for this experiment.

(c) Vocabulary: dilute

Step 2. Students follow procedures 1 to 8.

Period 3 -Step 2. (cont.) Students complete procedures 1 to 8.

Step 3. Students complete questions 1 to 4 (page 7).

Period 4 - Begin Expt. I-3. (page 8).

Purpose: To review the properties of water.

Step 1. Discuss water as in the introduction.

Step 2. Students follow procedures 1 to 5 (thought experiment).

Vocabulary: evaporate, condense, phase, dissolve.

Step 3. Students answer questions 1 to 4 (page 9).

Period 5 - Begin Expt. I-4. (page 9).

Purpose: To investigate phase changes of water.

Step 1.(a) Teach the class the correct use of a bunsen burner (refer to Appendix 1, page 196).

(b) Review vocabulary from Period 2.

(c) Define the purpose of this experiment.

Step 2. Students follow procedures 1 to 4.

Step 3. Students complete questions 1 to 4 (page 10).

Period 6 - Begin Expt. I-5. (page 11).

Purpose: To investigate diffusion in liquids.

Step 1. Tell students that this experiment will provide a clue about what matter is made of.

Step 2. Students follow procedure 1 and make sketches. Vocabulary: diffusion.

Step 3. Students answer questions 1 to 4, 6, 7 (page 11, 12).

Period 7 - Begin Expt. I-6. (page 12).

Purpose: To develop a particle model of matter.

Step 1. Discuss the introduction and define the purpose of this experiment.

Step 2. Demonstrate procedures 1 to 10. Stop for discussion after each demonstration.

Step 3. Students answer questions 1 to 4 (page 14).

Period 8 - Begin Expt. I-7. (page 15).

Purpose: To see what happens when particles of different sizes are mixed.

Step 1.(a) Discuss the size of particles in different substances (see introduction).

(b) Define the purpose of this experiment

Step 2. Students follow procedures 1 to 6.

Step 3. Students answer questions 1 to 5 (page 16).

Period 9 - Begin Expt. I-8. (page 17).

Purpose: To investigate diffusion in gases.

Step 1.(a) Review the particle model.

(b) Extend the particle model to include particles of different masses (see introduction).

(c) Define the purpose of this experiment.

Step 2.(a) Demonstrate procedures 1 and 2.

(b) Students follow procedures 3 to 10.

Step 3. Students answer questions 1 to 4 (page 19).

Period 10 - Begin Expt. I-9. (page 20).

Purpose: To find out if gases and liquids can be compressed.

Step 1.(a) Review particle model (as in introduction).

(b) Define the purpose of this experiment.

Step 2.(a) Students follow procedures 1, 2, 3, 5, 6.

(b) Students follow procedure 4 (graph).

Period 11 -Step 3. Students answer questions 1 to 6 (page 21).

Begin Expt. I-10. (page 22).

Purpose: To investigate sublimation.

Step 1.(a) Review the particle model.

(b) Review phase changes.

(c) Define the purpose of this experiment and discuss the procedure.

Period 12 -Step 2. Students follow procedures 1 to 6.

Step 3. Vocabulary: sublimation

Students answer questions 1 to 6 (page 23).

Period 13 - Begin Expt. I-11. (page 24).

Purpose: To investigate solutions.

Step 1.(a) Vocabulary: solution, solute, solvent, concentrated, saturated, solubility.

(b) Define the purpose of this experiment.

Step 2. Students follow procedures 1 to 7.

Period 14 - Step 3. Students answer questions 1 to 7 (page 25):

Begin Expt. I-12. (page 26),

Purpose: To measure the solubility of potassium nitrate.

Step 1.(a) Teach students how to use the centigram balance. (See Appendix 3, page 200).

Period 15 - Step 1.(b) Review vocabulary for solutions.

(c) Define the purpose of the experiment.

Step 2. Students follow procedures 1 to 7.

Period 16 - Step 3. Students answer questions 1 to 9 (page 28). Discuss the graph for question 9 with reference to procedure 8.

Period 17 - Begin Expt. I-13. (page 29).

Purpose: To find the density of water.

Step 1.(a) Review length, area and volume (see Appendix 2, page 197), and use worksheets for practice and reinforcement. Discuss the use of units such as c.c. or cm^3.

Period 18 - Step 1.(b) Develop the concept of density, e.g. Which is heavier, a pound of feathers of a pound of lead?

(c) Define the purpose of this experiment -- to find the mass of 1 ml. (or 1 cm^3.) of water.

(d) Show the use of a graduated cylinder and medicine dropper to obtain accurate measurements.

Step 2. Students follow procedures 1 to 6.

Period 19 - Step 2. (cont.) Students follow procedures 8, 9. (Allow students to try to find the density of ice.)

Step 3.(a) Students answer questions 1 to 4 (page 31).

Period 20 - Begin Expt. I-14. (page 32).

Purpose: To find the densities of different materials.

Step 1.(a) Review density concept.

(b) Discuss with students methods of finding the volume of a solid (see Appendix 5, page 205).

Step 2.(a) Students follow procedures 1 to 6.

Period 21 - Step 2.(b) Discuss results from procedures 1 to 6.

Step 2.(c) Students follow procedure 7.

Step 3.(a) Students answer questions 1 to 9 (page 33-35).

Period 22 - Step 3.(b) Discuss answers to questions 1 to 9.

Begin Expt. I-15. (page 35).

Purpose: To see what happens to mass when a chemical change occurs in a closed system.

Step 1.(a) Vocabulary: chemical reaction or chemical change, substance.

(b) Define the purpose of this experiment.

(c) Demonstrate the correct technique for filtering.

Period 23 - Step 2. Students follow procedures 1 to 10.

Step 3. Students answer questions 1 to 6 (page 36).

Period 24 - Begin Expt. I-16. (page 37).

Purpose: To study mass change during a chemical reaction in an open system.

Step 1. Define the purpose of this experiment.

Step 2. Students follow procedures 1 to 4.

Step 3. Students answer questions 1 to 4 (page 38).

Period 25 - Begin Expt. I-17. (page 38).

Purpose: To measure the rate of a chemical reaction.

Step 1.(a) Discuss "rate" of a reaction and its importance (see introduction, page 38).

(b) Define the purpose of this experiment.

Students follow the procedures 1 to 6.

Period 26 - Step 3. Students answer questions 1 to 4 (page 39).

Period 27 - Begin Expt. I-18. (page 40).

Purpose: To see how a catalyst speeds up a chemical reaction.

Step 1.(a) Vocabulary: catalyst.

(b) Define the purpose of this experiment.

(c) Warn students of the dangers of acid.

Step 2. Students follow procedures 1 to 8.

Step 3. Students answer questions 1 to 4 (page 41).

Labtext in Science, Book 1 (Method 2)

Period 1 - Begin Section 8: The Nature of Stuff.

Purpose: To gather evidence to develop a model of matter.

Step 1.(a) Discuss some of the properties of matter (see 8.A.1) and make students see that we want to know why things behave as they do.

(b) Discuss models in general (e.g. solar system) and the need for a model.

(c) Define the purpose of section 8.

(d) Vocabulary: phase or state.

Step 4. Teacher demonstrates 8.A.2 (mercury and glass chips) and students are to list as many observations as possible.

Step 5. List all the observations on the blackboard and have students answer verbally the questions asked in 8.A.2.

Period 2 - Step 1.(a) Vocabulary: diffusion.

(b) Define the purpose of 8.B.1.

Step 2.(a) Read and discuss 8.B.1 and explain modifications in apparatus. Demonstrate what happens when ammonia gas and HCl gas mix.

(b) Caution students on the use of the chemicals.

Step 4. Students follow the outline in 8.B.1 and list observations.

Step 5. List all observations on the blackboard.

Step 6. Have students use these observations to answer the questions at the end of 8.B.1 (verbally).

Period 3 - Step 7. Discuss the procedure used in 8.B.1 and have students suggest modifications to help explain the questions more clearly.

Step 8. Students perform 8.B.1 again and make careful observations.

Step 9. Students write answers to the questions in 8.B.1.

Period 4 - Step 1. Teach the correct way to use a bunsen burner and the correct way to heat water in a test tube.

Step 2.(a) Read and discuss 8.C.1 and tell students that they are to make careful written observations that will have to be explained by their "model."

Step 4.(a) Students follow 8.C.1 and list observations.

Period 5 - Step 5.(a) Discuss the results of 8.C.1.

Step 6.(a) Students try to explain 9.C.1 in terms of their model.

Step 2.(b) Read and discuss 8.C.2. Remind students that observations will have to be explained by the model.

Step 4.(b) Students follow 8.C.2.

Step 5.(b) Discuss the results of 8.C.2.

Step 6.(b) Students try to explain 8.C.2 in terms of their model.

Period 6 - Step 1. Vocabulary: evaporation, condensation, melting, freezing, sublimation.

Step 4.(a) Demonstrate 8.A.3 (bromine tubes). Students make written observations.

(b) Demonstrate 8.A.4 (iodine tubes). Students make written observations.

Step 5. List observations on the blackboard and note those common to iodine and bromine.

Step 9.(a) Students write an explanation of observations in terms of the particle model.

(b) Students answer 8.D. Nos. 2, 3.

Period 7 - Step 1. Review vocabulary: diffusion.

Step 2. Students follow 8.B.2 and make careful observations.

Step 5. List observations on the blackboard and again have students formulate questions to be answered by the particle model.

Step 6. Discuss possible answers to these questions but do not add any information other than what the students supply.

Period 8 - Step 1. Review vocabulary: sublimation.

Step 2. Read and discuss 8.B.3.

Step 3. Students try to predict what will happen.

Step 4. Students perform 8.B.3 and list all observations.

Step 5. List all observations on the blackboard and have students group those that are relevant to sublimation.

Period 9 -	Step 7.	Discuss the procedure and have students rewrite the procedure to improve the experiment; make new predictions.
	Step 8.	Students follow their new procedure.
	Step 9.	Students write answers to questions in 8.B.3.
Period 10 -	Step 1.	Tell students that the following demonstrations will imitate the behavior of matter.
	Step 4.	Demonstrate 8.A.6 and 8.A.7.
	Step 5.	List observations on the blackboard and have students write a description of the behavior of the particles in each of the three phases of matter.
	Step 9.	Students explain questions 1, 2, 4 (page 82) in 8.A.7. Assign Chapter 19 of R.A.S., page 83.
Period 11 -	Step 1.(a)	Vocabulary: compress.
	(b)	Define the purpose of 8.B.4.
	Step 2.	Read and discuss 8.B.4; students design a data table to record observations.
	Step 4.	Students perform 8.B.4 with air and then with natural gas.
Period 12 -	Step 6.	Students draw a graph of the results for each gas. Discuss the graphs.
	Step 9.	Students answer questions in 8.B.4.
Period 13 -	Step 1.(a)	Vocabulary: volume, litre, millilitre.
	(b)	Teach students the correct use of a graduated cylinder to measure liquid volume.
	(c)	Define the purpose of 8.B.5.
	Step 2.	Read and discuss 8.B.5.
	Step 4.(a)	Students follow 8.B.5.
	Step 1.(d)	Teach students the correct filtration technique.
	Step 4.(b)	Students separate the sand and water by filtration.
Period 14 -	Step 9.	Students answer the final questions in 8.B.5. Discuss the answers.
	Step 1.	Define the purpose of 8.B.6.
	Step 2.	Read and discuss 8.B.6.

Step 3. Students make a prediction for 8.B.6.

Step 4. Students perform 8.B.6.

Step 9. Students answer the questions in 8.B.6. Discuss the answers.

Period 15 - Step 1. Define the purpose of 8.B.7.

Step 2. Read and discuss 8.B.7.

Step 4.(a) Students follow 8.B.7 and record observations.

(b) Demonstrate 8.C.4; students record observations.

Step 9.(a) Have students explain observations from 8.B.7 and 8.C.4 using the Kinetic Molecular Theory.

(b) Students answer 8.D., questions 4, 5, 6, 7, 10, 12, 13, 18, 19, 22, as an assignment.

Period 16 - Begin Section 9: Bulk Properties of Matter.

Purpose: To study some properties of materials that will be useful in identification.

Step 1. Discuss properties of matter as in 9.A.1, and define the general purpose of this section.

Step 2. Read and discuss 9.B.1.

Step 4. Students follow 9.B.1 and make observations.

Step 6. Students explain observations using the particle theory.

Period 17 - Step 1.(a) Define the purpose of 9.B.3.

(b) Teach students how to read a thermometer.

Step 2.(a) Read and discuss 9.B.3 (use paradichlorobenzene).

Step 4.(a) Students perform 9.B.3 and record all readings in a suitable table.

Step 5.(a) List the melting points and freezing points for each group on the blackboard and have students calculate the averages.

Period 18 - Step 2.(b) Students are to gather data for a cooling curve. Explain the procedure -- melt the substance to about 10C° above the melting point and record the temperature every 30 seconds as it cools, until the substance has completely solidified.

Step 4.(b) Students proceed as above.

Step 5.(b) Students draw a cooling curve and estimate the melting temperature.

Step 7. Discuss the procedure and have students suggest modifications.

Period 19 -	Step 1.	Define the purpose of 9.B.4.
	Step 2.	Read and discuss 9.B.4.
	Step 3.	Students predict the results of 9.B.4.
	Step 4.	Students perform 9.B.4 and record observations.
Period 20 -	Step 5.	Students draw a graph of their results and compare with predictions.
	Step 6.	Students make a general conclusion about the temperature of a boiling liquid.
	Step 7.	Discuss the procedure and any suggested modifications.
	Step 9.	Students explain "boiling" in terms of the Kinetic Theory.
Period 21 -	Step 1.	Define the purpose of 9.C.4; Students are to find the answer to the first question in 9.C.4.
	Step 3.	Students design their procedure and predict the results.
	Step 4.	Students follow their procedure and record all observations.
	Step 6.	Discuss the results of 9.C.4 and compare with predictions.
	Step 7.	Discuss the procedures followed.
Period 22 -	Step 1.(a)	Teach the use of a centigram balance.
	(b)	Discuss the difference between mass and weight as in 9.A.2.
	Step 2.	Read and discuss 9.B.5.
	Step 4.	Students follow 9.B.5 and record all readings.
	Step 1.(a)	Define the purpose of 9.B.6.
	(b)	Worksheet on volume of solids.
Period 23 -	Step 2.(a)	Read and discuss the first part of 9.B.6 (using 1 cm^3 cubes).
	Step 4.(a)	Students follow the first part of 9.B.6 and complete the first data table.
	Step 5.(a)	Compare class results for the mass of 1 cm^3 of different solids.
Period 24 -	Step 2.(b)	Read and discuss the second part of 9.B.6. (Note: find the volume of the cylinders by displacement.)
	Step 4.(b)	Students follow the second part of 9.B.6 and complete the second data table.

Step 5.(b) Compare class results for the mass of 1 cm^3 of of each solid.

(c) Compare the results for the two parts of 9.B.6.

Step 6. Define *density* and relate it to the experiment.

Period 25 - Step 1. Define the purpose of 9.B.7. Students are to find the density of a small tangle of copper wire.

Step 3. Students design their own procedure and predict results.

Step 4. Students follow their procedure and calculate the density of the wire.

Step 5. Compare class results and compare with predictions.

Step 6. Have students make a general conclusion about the density of a substance.

Period 26 - Step 1. Define the purpose of 9.C.5. Students are to find the density of water.

Step 2. Read and discuss 9.C.5.

Step 4. Students follow 9.C.5 and complete the data table.

Step 5. Compare class results.

Step 6. Make a general conclusion about the density of water.

Step 9. Students answer 9.D., Questions 3, 4, 7.

Period 27 - Step 1.(a) Vocabulary: solution, solute, solvent, (9.A.3).

(b) Define the purpose of 9.B.8. (To find the solubility of saltpeter at room temperature and at near boiling.)

Step 2. Read and discuss 9.B.8 and explain modifications as follows:

1. Find out how many spoonfuls of saltpeter will dissolve in 25 ml. of water at room temperature.
2. Heat the solution to almost boiling and repeat.
3. Watch the solution as it cools.

Step 4. Students follow the procedure as above and record all observations.

Step 5. Discuss class results for 9.B.8 so far.

Period 28 - Step 1.(a) Again define the purpose of 9.B.8. (Students are to use the saturated solution from above to find the solubility of potassium nitrate in grams by evaporation.)

(b) Vocabulary: saturated.

Step 2. Discuss with students the procedure to be designed.

Step 3. Students design their own written procedure.

Step 4. Students follow their own procedure.

Step 5. Collect class results on the blackboard and discuss these.

Period 29 - Step 1. Define the purpose of 9.B.9 (modified): Students are to separate a mixture of sand and salt.

Step 2. Discuss the necessary steps.

Step 3. Students write their own procedure.

Step 4. Students follow their own procedure and return to the teacher the separated salt and sand.

Period 30 - Step 1. Define the purpose of 9.B.10.

Step 2. Read and discuss 9.B.10.

Step 3. Students predict how many bottles of gas will be in a bottle of pop.

Step 4. Students follow 9.B.10.

Step 5. Compare results for different types of pop.

Step 9. Assignment: Students answer 9.D. Questions w, 12, 13, 19, 29.

Period 31 - Begin Section 10: Reactions of Matter.

Purpose: To study some properties of chemical reactions.

Step 1.(a) Discuss chemical reactions (10.A.1).

Vocabulary: Substance, chemical reaction, open and closed systems.

(b) Define the purpose of 10.B.1.

Step 2. Read and discuss 10.B.1.

Students predict what will happen to the mass in 10.B.1.

Step 4. Students follow 10.B.1 and record all observations.

Step 6. Compare results with predictions.

Step 9. Students answer questions at the end of 10.B.1.

Period 32 - Step 1. Define the purpose of 10.B.2.

Step 2. Read and discuss the procedure for 10.B.2.

Students predict the results for 10.B.2.

Step 4. Students follow 10.B.2 and list all observations.

Step 6. Compare results with predictions and discuss.

Step 9.(a) Students explain what happened to the lost mass.

(b) Students answer 10.D. No. 4.

Period 33 - Step 1.(a) Define the purpose for 10.B.3.

(b) Vocabulary: crucible.

Step 2. Read and discuss 10.B.3.

Step 4. Students follow 10.B.3 and list all observations.

Step 6. Discuss results and have students attempt to explain these results.

Step 9. Students answer questions in 10.B.3.

BIOLOGY UNIT

Introducing Science Concepts in the Laboratory (Method 1)

Unit II: Living Things Detect and Respond to Stimuli.

Period 1 - Begin Expt. II-1. (page 43).

Purpose: To compare the growth of different seedlings.

Step 1.(a) Vocabulary: biology, organism, stimulus, stimuli.

(b) Define the purpose of this experiment.

Step 2. Students follow procedures 1 to 9.

Period 2 - Step 2. (cont.) Students complete procedures 1 to 9.

Step 3. Students answer questions 1, 2, 3. (page 44).

Begin Expt. II-2. (page 45).

Purpose: To find out how living things differ from non-living things.

Step 1.(a) Ask students for obvious examples of living and non-living things. Discuss differences of opinion (e.g. a dry seed).

(b) Define the purpose of this experiment.

Period 3 - Step 2.(a) Students follow procedures 1 to 3.

(b) Teacher demonstrates procedures 4 and 5 (micro-projector) and students make observations.

(c) Students follow procedures 6, 7, 8.

Period 4 - Step 3. Students answer questions 1 to 6, page 46. (To be completed for homework).

Begin Expt. II-3. (page 47).

Purpose: To find out how growing plants respond to light.

Step 1.(a) Ask students to name some stimuli that might affect the growth of plants. (Vocab: environment).

(b) Discuss positive and negative responses.

(c) Define "tropism" and show the different types as listed on page 48.

(d) Define the purpose of this experiment.

Step 2.(a) Students follow procedures 1 to 5.

Period 5 - Step 2.(b) Students follow procedures 6 to 9. (Note: Procedures 8 and 9 continue throughout the next 5 or 6 periods until students are satisfied with the results.)

Step 3.(a) Discuss the nature of a controlled experiment and the concept of constant and variable factors (refer to procedure 6).

(b) Have students point out how various factors are controlled in this experiment.

(c) Explain how hormones affect behavior and growth, and refer to RAS Chapter 8.

(d) Students answer questions 1 to 4. (page 50).

Period 6 - Begin Expt. II-4. (page 52).

Purpose: To find out how growing plants respond to gravity.

Step 1.(a) Ask students why roots grow down and stems grow up: lead up to gravity.

(b) Discuss control of other variables.

(c) Define the purpose of this experiment.

Step 2.(a) Students follow procedures 1 to 8. Note: This experiment is to be continued in periods 9 and 10.

Period 7 - Modification of Expt. II-5.

Purpose: To investigate the nature of nastic movements.

Step 1.(a) Discuss plants such as Mimosa and Venus Fly Trap (samples present).

(b) Define the purpose of this experiment.

Step 2. Students demonstrate procedures 2 and 6.

Step 3.(a) Discuss the difference between a tropism and a nastic response. (A tropism is a growth response and a nastic movement is movement in the same direction regardless of stimulus direction).

(b) Students answer questions 1 and 3. (page 56).

(c) Show film on plant movement.

Period 8 - Step 2(cont. from period 6) Students follow procedures 9 and 10 in Expt. II-4.

Begin Expt. II-6. (page 58).

Purpose: To study the structure of earthworms.

Step 1.(a) Discuss differences between plants and animals, with emphasis on the nervous system.

(b) Define the purpose of this experiment.

Step 2.(a) Students follow procedures 1 to 7.

Period 9 - Step 2 (cont. from periods 6 and 8) Students follow procedure 11 in experiment II-4.

Step 3.(a) Discuss results of Expt. II-4.

(b) Assign questions 1 to 5 (page 54) for homework.

Step 2.(b) Students complete procedures 1 to 7 of Expt. II-6.

Step 3.(a) Review with the class the observations on the earthworm.

(b) Students answer questions 1, 2, 3, 5, 6. (page 60).

Period 10 - Begin Expt. II-7. (page 60).

Purpose: To study the responses of earthworms.

Step 1.(a) Review earthworms' method of movement.

(b) Define the purpose of this experiment.

Step 2.(a) Divide the class into 2 groups and assign each group either part A or part B.

(b) Students follow the procedure for their part of the experiment.

(c) All students do part C, procedures 12, 14, and 15.

Period 11 - Step 3.(a) Summarize results of parts A and B on the blackboard. (data table).

(b) Review results of part C.

(c) Define taxis, and review tropism and nastic movement.

(d) Students answer questions 1 to 4 (page 62).

Period 12 - Begin Expt. II-8, page 63. Note: Expts. II-8 and II-9 depend on arthropods being available.

Step 1.(a) Vocabulary: arthropod, thorax, abdomen.

(b) Define the purpose. (To study the structure of arthropods).

Step 2. Students follow procedures 1 to 6.

Period 13 - Step 2. (cont.) Students complete procedures 1 to 6 of Expt. II-8.

Step 3.(a) Review the structure of arthropods: body covering, legs, eyes, mouth, body, wings.

(b) Students answer questions 1 to 7, page 65. (Complete for homework).

Period 14 - Begin Expt. II-9 (page 66).

Purpose: To study the responses of arthropods.

Step 1.(a) Review the structure of arthropods.

(b) Define the purpose of this experiment.

Step 2.(a) Students choose one of parts A, B, C, or D.

(b) Students follow the procedure for their selected part.

Period 15 - Step 3.(a) Summarize the findings for each part on the blackboard.

(b) Students answer questions 1 to 5. (page 69).

Period 16 - Begin Expt. II-10. (page 70).

Purpose: To study the structure and responses of a fish.

Step 1.(a) Discuss the function of a backbone.

Vocabulary: vertebrate, invertebrate.

(b) Define the purpose of this experiment.

Step 2. Students follow procedures 1 to 10.

Period 17 - Step 2. (cont.) Students complete procedures 1 to 10.

Period 18 - Step 3.(a) Discuss results of the investigation; summarize on the blackboard.

(b) Students answer questions 1, 2, 3, 6, 7, 8. (page 73).

Period 19 - Begin Expt. II-11. (page 74).

Purpose: To examine your own sense of sight.

Step 1. Define the purpose of this experiment.

Step 2. Students follow procedures 1 to 10.

Period 20 - Step 2. (cont.) Students complete procedures 1 to 10.

Step 3.(a) Discuss findings: control of pupil size, focussing, stereo vision, blind spot, movement, peripheral vision.

(b) Cross-sectional view of the eye. (diagram).

(c) Students answer questions 1 to 7, page 77. (Complete for homework).

Period 21 - Begin Expt. II-14: A Field Study (page 84).

Purpose: To study an organism in its natural setting.

Step 1.(a) Explain the purpose of this study.

(b) Discuss the procedure and read examples on page 85.

Step 2. Assign students to chose an organism and find out how it reacts to its environment. Results are to be presented on a wall-chart.

Period 22 - Begin Expt. II-12 (page 78).

Purpose: To study the structure of the eye.

Step 1.(a) Define the purpose of this experiment.

(b) Review the structure of the eye.

(c) Show the correct use of forceps, tongs, scissors, and razor blade for the purpose of dissection.

Step 2. Students follow procedures 1 to 10.

Period 23 - Step 2. (cont.) Students complete procedures 1 to 10.

Step 3. Students answer questions 1 to 5. (page 80).

Period 24 - Begin Expt. II-13. (page 81).

Purpose: To study learned responses. (maze learning).

Step 1.(a) Define the purpose of this experiment.

(b) Vocabulary: learning, trial and error learning.

(c) Show a maze and explain that 3 choices or decisions must be correctly made to reach the goal.

Step 2. Students follow procedures 2, 3, and 4.

Period 25 - Step 3.(a) Discuss and compare results; use students' results as examples.

(b) Students answer questions 1 to 8. (page 83).

Labtext in Science, Book 1 (Method 2)

Period 1 - Begin Section 11: The Living and the Non-living.

Purpose: (a) To distinguish between living and non-living things.

(b) To investigate the growth rate of moulds.

Step 1.(a) Ask students to decide what living things do that distinguishes them from non-living things. (This is a general discussion only as more of this follows in 11.A.3.)

(b) Vocabulary: biology, organism. (11.A.1).

(c) Define the purposes.

Step 2. Read and discuss 11.A.2 and 11.B.1.

Step 3. Students set up the experiments in 11.A.2 and 11.B.1.

Period 2 - Step 4. Students make observations on 11.A.2 and 11.B.1.

Step 5.(a) Discuss life processes in more detail (11.A.3).

(b) Discuss methods of reproduction of moulds. (11.A.4). Assign students to investigate this from references.

(c) Discuss different types of mould and their mediums. Students must then choose one of the questions in 11.C.1, and set up an experiment to answer the question.

Period 3 - Step 4. (cont.) Students make observations on 11.A.2, 11.B.1, and 11.C.1.

Step 5. (cont.) List observations from 11.A.2 and 11.B.1 and the blackboard.

Step 6. By discussion, group the observations in terms of living and non-living characteristics, (mould versus rust) and compare with previously listed life processes.

Step 7. Ask students to suggest modifications for an improvement of 11.B.1.

Period 4 - Begin Section 12: Controlled Experiments in Biology.

Purpose: (a) To learn how to control an experiment.

(b) To investigate the effects of various stimuli on the growth of moulds.

Step 1.(a) Discuss 12.A.1; Vocabulary: stimulus, stimuli, variables.

(b) Discuss the "thought experiment" in 12.A.2, and have students suggest how the variables could be controlled.

(c) Define the purpose of 12.B.1.

Step 2. Read and discuss 12.B.1 and discuss the variables that must be controlled.

Step 3. Students prepare a written procedure for 12.B.1, and make a prediction of expected results.

Step 4.(a) Students prepare 12.B.1 according to their own procedure.

(b) Students choose one of 12.C.1, 12.C.1, 12.C.3, or 12.D.1, and prepare an experiment to answer the question asked.

Period 5 - Step 4.(c) Students make observations on 12.B.1 and their own selected experiment.

Step 9. Students answer questions in 12.D.2, 12.D.3, 12.D.4.

Period 6 - Step 4.(d) (cont.) Students make continued observations on 12.B.1 and their selected experiment.

Step 5. List observations on the blackboard and discuss.

Step 6. Make conclusions about the effects of the variables used and compare with predictions.

Step 7. Discuss any variations in procedure and have students suggest any improvements needed in their design.

Step 8. Students can set up a re-run of the experiment if they wish.

Period 7 - Begin Section 13: Plants and their Response to Stimuli.

Purpose: To perform controlled experiments to see how plants respond to various stimuli.

Step 1. Discuss with the class the various stimuli that may affect the growth of plants.

Step 2.(a) Read carefully the outline of 12.B.1 and ask students if any modifications could be suggested.

Step 3.(a) Students set up the radish seeds as described in 13.B.1, and make a prediction of the results. Continued observation is necessary for the next 4 or 5 days.

Step 2.(b) Discuss other stimuli and guide the discussion to the effects of gravity. Read the outline for 12.B.2 and ask students to suggest modifications.

Period 8 - Step 3.(b) Students set up 13.B.2 and predict the results. Record any necessary observations for 13.B.1.

Step 2.(c) Read the questions in 13.C.1 and 13.C.2 and have students pose other similar questions regarding different stimuli. Students are to select one of these questions and describe the procedure for testing the effect of that stimulus.

Step 3.(c) Students set up their experiment to test the selected stimulus according to their procedure.

Period 9 - Step 3.(d) Students make observations on the three experiments they have in progress.

Step 4.(a) Explain the meaning of "tropism" and define the various tropisms that may be encountered. (N.B. Magnetotropism.)

(b) Discuss positive and negative responses.

(c) Show film on plant movements.

Period 10 - Step 3.(e) Record observations for the three experiments. Rotate seed containers for 13.B.2.

Step 4.(b) Demonstrate the effects of touching a Mimosa plant and a Venus Fly Trap. Explain the nature of a nastic response.

Step 4.(c) Read Chapter 8 of R.A.S. and discuss the effects of auxins on roots and stems.
Vocabulary: hormone, auxin.

Period 11 - Step 3.(f) Record observations for the three experiments.

Step 5. Discuss results of these experiments and compare the generalized results with the predictions.

Step 7. Ask students for modifications of the experiment that might improve the results.

Step 9. Students answer questions in 13.B.1, 13.D.1, and 13.B.2.

Period 12 - Begin Section 14: Animals and their Response to Stimuli.

Purpose: To perform controlled experiments to see how animals respond to stimuli.

Step 1.(a) Review stimuli and name those that may affect animals.

(b) Vocabulary: anterior, posterior, dorsal, ventral, lateral, setae, anus, clitellum.

Step 2. Read and discuss 14.A.1

Step 4. Students follow the outline in 14.A.1 and make a diagram of their worm and label the respective parts as observed.

Step 5. Class discussion to compare observations: e.g. number of segments, setae, food in digestive tract, etc.

Period 13. Step 1.(a) Vocabulary: taxis and types of taxes. Relate to tropisms.

(b) Define the purposes of 14.B.1 and 14.B.2.

Step 2. Read and discuss 14.B.1 and 14.B.2.

Step 3. Students predict results for 14.B.1 and 14.B.2.

Step 4. Students perform 14.B.1 and 14.B.2 and list all observations.

Step 5. List observations for 14.B.1 and 14.B.2 on the blackboard. (Data table).

Step 6. Compare results with predictions.

Step 7. Discuss procedure for 14.B.2 and have students suggest modifications for a re-run. Make new predictions.

Step 8. Perform re-run if time allows.

Step 9. Students answer questions in 14.B.1, 14.B.2, 14.D.1, 14.D.2, 14.D.3, 14.D.4, and 14.D.5.

Period 14 - Step 1.(a) Vocabulary: Planarian, planaria, pharynx.

(b) Define the purpose for 14.A.3 and 14.B.3.

Step 2. Read the outline for 14.A.3 and 14.B.3.

Step 3. Students predict the results for 14.B.3.

Step 4.(a) Students follow 14.A.3 and make a diagram of a planarian and make all observations on the diagram.

(b) Students follow 14.B.3 and list all observations.

Step 5. List all observations for 14.B.3 on the blackboard.

Step 6. Make a conclusion for 14.B.3 and compare with predictions.

Step 7. Have students devise a better way to perform 14.B.3.

Step 8. Students follow their revised method.

Step 9. Students answer the question in 14.B.3.

Period 15 and 16 - Step 1. Define the purpose: Students are free to devise an experiment to test brine shrimp using any practical variable.

Step 2. Discuss with the class some of the possible experiments. (see 14.C.3).

Step 3. Students concoct their written procedure and predict the results.

Step 4. Students follow their procedure and list all observations, including a diagram.

Step 5. Class discussion: students give a brief report of their results. List these on the blackboard.

Step 6. Compare the conclusions with the predictions.

Step 7. Discuss modifications that are felt necessary for any of the experiments, especially if conflicting reports arise.

Step 8. If appropriate, perform re-runs of the experiments.

Period 17 - Step 1.(a) Define the purpose for 14.B.5.

(b) Vocabulary: receptors (sense organs).

(c) Show how to use a cm. ruler and how to make and use the simple apparatus.

Step 2. Read and discuss the outline in 14.B.5 and show students how to use the data table. Encourage students to make their own data table if the one given seems inappropriate to them.

Step 3. Students make a prediction of the results.

Step 4. Students follow the method of testing given and record observations in their data table.

Step 6. Students examine their completed table and list the areas in order of increasing sensitivity.

Step 7. Compare these results with predictions.

Step 9. Students answer questions in 14.B.5.

Period 18 -	Step 1.	Define purpose: Students are to choose one of 14.C.5, 14.C.6, or 14.C.7.
	Step 3.	Students make an outline of the procedure they will perform and design a data table. Predictions should be made.
	Step 4.	Students follow their procedure.
	Step 6.	Students make their conclusions and compare with the predictions. List conclusions on the blackboard.
Period 19 -	Step 1.(a)	Define purpose for 14.B.6 and assign it as a home experiment.
	Step 2.(a)	Discuss the outline of 14.B.6.
	Step 1.(b)	Define the purpose for 14.B.7.
	Step 2.(b)	Discuss the procedure for 14.B.7.
	Step 3.	Students construct a data table and make a prediction for 14.B.7.
	Step 4.	Pairs of students demonstrate while the class records observations.
	Step 6.	Compare results with predictions.
Period 20 -	Step 1.(a)	Define the purpose for 14.A.5 and 14.B.8.
	(b)	Vocabulary: Use the model of the eyeball to show the various parts. Students make a labelled diagram.
	Step 2.	Read and discuss the first two paragraphs of 14.B.8.
	Step 4.	Students follow the instructions in the first two paragraphs of 14.B.8.
Period 21 and 22 -	Step 1.(a)	Show the use of forceps, tongs, scissors, and razor blade for the purpose of dissection of the eye.
	(b)	Students make a table for observation in which they will list the parts of the eye and the appearance of each.
	Step 2.	Read and discuss the remainder of 14.B.8.
	Step 4.	Students disect the eye following the instructions in 14.B.8.
	Step 9.	Students list the parts of the eye and describe the function of each. (Refer to 14.A.5.)

Period 23 - Step 1.(a) Review the structure of the retina.

(b) Define the purpose of 14.B.9.

Step 2.(a) Read and discuss 14.B.9.

Step 4.(a) Students test their blind spot as in 14.B.9.

Step 9. Students explain why there is a blind spot in each eye.

Step 1.(c) Define the purpose of 14.B.10.

Step 2.(b) Read and discuss 14.B.10.

Step 4.(b) Students test their judgement of distance as in 14.B.10.

Step 1.(c) Define the purpose of 14.C.11.

Step 4.(c) Students follow outline in 14.C.11 and list their observations.

Step 5. Discuss the observations and form a conclusion about compound eyes.

Step 9. Students answer the question in 14.C.11.

Period 24 and 25 - Step 1.(a) Define the purpose of 14.A.6.

Step 2.(a) Read and discuss the outline in 14.A.6.

Step 4. Demonstrate as in 14.A.6, students make observations.

Step 6. Discuss the nature of the image formed. (This will be followed up in the Optics unit.)

Step 1.(b) Define the purpose of 14.B.11.

Step 2.(b) Read and discuss the outline in 14.B.11.

Step 4. Students test their peripheral vision as in 14.B.11, and also attempt to investigate their field of colour vision for different colours.

Step 5. Discuss the various observations noted.

Step 6. Have students make conclusions about their peripheral vision.

Step 9. Students answer questions in 14.B.11.

OPTICS UNIT

Introducing Science Concepts in the Laboratory (Method 1)

Period 1 - Unit IV: Light.

Begin Expt. IV-1.(page 145).

Purpose: To observe different types of light sources.

Step 1.(a) Discuss different types of light sources (see introduction).

(b) Vocabulary: Luminous, non-luminous, point source, broad source.

(c) Define the purpose of this experiment.

Step 2. Students follow procedures 1 to 8.

Step 3. Students answer questions 1, 3, 4, 5 (page 147). (Assign R.A.S. Chapters 26, 27; pages 120-125).

Period 2 - Begin Expt. IV-2. (page 148).

Purpose: To find the path that light follows.

Step 1.(a) Discuss the conditions for seeing light (introduction).

(b) Define the purpose of this experiment.

Step 2.(a) Demonstrate part A (procedures 1 to 3).

(b) Students follow procedure 4.

Step 3. Students answer questions 1 to 8 (pages 149-150). (Assign R.A.S. Chapter 28; page 126).

Period 3 - Begin Expt. IV-3. (page 151).

Purpose: To find out what happens when light strikes various objects.

Step 1.(a) Vocabulary: transparent, translucent, opaque.

(b) Define the purpose of this experiment.

Step 2. Students follow procedure 1.

Step 3. Students answer questions 1 and 2 (page 151).

Period 4 - Begin Expt. IV-4. (page 151).

Purpose: To study shadows.

Step 1. Define the purpose of this experiment.

Step 2. Students follow procedures 1 to 9.

Period 5 - Step 2. (cont.) Students complete procedures 1 to 9.

Step 3. Students answer questions 1 to 7 (pages 153-154). (Assign R.A.S. Chapter 30; page 132).

Period 6 - Begin Expt. IV-5. (page 155).

Purpose: To see what happens when light from a candle passes through a pinhole and strikes a screen.

Step 1. Define the purpose of this experiment.

Step 2. Students follow procedures 1 to 10.

Step 3. Students answer questions 1 to 6 (pages 156-157).

Period 7 - Step 3. Students complete questions 1 to 6. Discuss answers to these questions.

Begin Expt. IV-6. (page 158).

Purpose: To study refraction of light by a transparent solid.

Step 1.(a) Teach students the correct use of a protractor. (See Appendix 7, page 206. Use a worksheet for practice in measuring, naming and constructing angles.)

Period 8 - Step 1.(b) Vocabulary: perpendicular, right angle, normal, incident ray.

(c) Define the purpose of this experiment.

Step 2. Students follow procedures 1 to 8. Discuss the results obtained.

Period 9 - Step 3. Students answer questions 1 to 5 (pages 160-161).

Begin Expt. IV-7. (page 162).

Purpose: To study light passing through lenses.

Step 1.(a) Relate the use of lenses to various optical equipment.

(b) Vocabulary: parallel beam, converge, diverge, cylindrical, convex, concave.

Period 10 - (c) Define the purpose of this experiment.

(d) Vocabulary: principal axis, lens axis, optical centre.

Step 2.(a) Students follow procedures 1 to 3.

(b) Discuss results and define principal focus and focal length.

(c) Students follow procedures 4 to 8.

Period 11 - Step 3. Students answer questions 1, 2, 3, 6, 7, 8 (pages 165-166).

Period 12 - Begin Expt. IV-8. (page 166).

Purpose: To use a spherical convex lens to produce an image.

Step 1.(a) Vocabulary: spherical.

(b) Define the purpose of this experiment.

Step 2. Students follow procedures 1 to 8.

Vocabulary: virtual image.

Period 13 - Step 3. Students answer questions 1 to 5 (page 168).

Begin Expt. IV-9. (page 171).

Purpose: To study how an eye works and how to correct defects in vision.

Step 1.(a) Review the structure of the eye.

(b) Define the purpose of this experiment.

Period 14 - Step 2.(a) Students follow procedures 1 and 2.

(b) Discuss results and relate these to the functioning of the eye.

(c) Students follow procedures 3 to 6.

(d) Discuss results.

Step 3. Students answer questions 1 to 6, and 9 (page 173-174).

Period 15 - Begin Expt. IV-10. (page 175).

Purpose: To see how light passes through a prism.

Step 1.(a) Vocabulary: prism.

(b) Define the purpose of this experiment.

Step 2.(a) Students follow procedures 1 to 5.

Period 16 - Step 1.(c) Vocabulary: spectrum, ROYGBIV (colours of the spectrum).

Step 2.(b) Students follow procedures 6 to 9.

Step 3. Students answer questions 1, 4, 5 (pages 177-178).

Period 17 - Begin Expt. IV-11. (page 179).

Purpose: To study reflection from a plane mirror.

Step 1.(a) Vocabulary: plane.

(b) Define the purpose of this experiment.

Step 2.(a) Students follow procedures 1 to 7.

Period 18 - Step 1.(c) Vocabulary: normal, incident ray, reflected ray, angle of incidence, angle of reflection.

Step 2.(b) Students follow procedures 8 to 12.

Period 19 - Step 1.(d) Vocabulary: diffuse reflection.

Step 2.(c) Students follow procedures 13 and 14.

Step 3. Students answer questions 1 to 13 (pages 181 to 183).

Period 20 - Begin Expt. IV-12. (page 183).

Purpose: To find the image formed by a plane mirror.

Step 2. Students follow procedures 1 to 8.

Period 21 - Step 3. Students answer questions 1 to 3 (page 185).

Begin Expt. IV-13. (page 186).

Purpose: To study reflection from curved cylindrical mirrors.

Step 1.(a) Vocabulary: cylindrical.

(b) Define the purpose of this experiment.

Period 22 - Step 2. Students follow procedures 1 to 3.

Vocabulary: converge, diverge, parabolic, principal axis, principal focus, focal length.

Step 3. Students answer questions 1 to 5 (pages 187-188).

Period 23 - Begin Expt. IV-14. (page 189).

Purpose: To study images formed by curved mirrors.

Step 1.(a) Review vocabulary: concave, convex, spherical.

(b) Define the purpose of this experiment.

Step 2. Students follow procedures 1 to 3.

Period 24 - Step 3. Students answer questions 1 to 6 (page 190).

Labtext in Science, Book 1 (Method 2)

Period 1 -		Begin Section 3: How Light Travels.
		Purpose: To investigate the path of light and the formation of shadows.
	Step 1.(a)	Discuss "What is light?"
	(b)	Define the purpose of this section.
	Step 4.	Demonstrate as in 3.A.1.
		Vocabulary: luminous, non-luminous.
	Step 5.	List observations from 3.A.1 on the blackboard and discuss questions asked in 3.A.1.
	Step 2.	Read and discuss 3.B.1(a).
	Step 4.	Students follow 3.B.1(a).
	Step 6.	Students use observations to answer questions in 3.B.1(a). (Assign R.A.S. Chapters 26, 27; pages 120-125).
Period 2 -	Step 1.	Show students how to use a ray box.
	Step 2.	Read and discuss 3.B.1(b).
	Step 4.	Students follow 3.B.1(b) and answer the questions.
	Step 1.	Vocabulary: transparent, translucent, opaque.
	Step 2.	Read and discuss 3.B.2.
	Step 4.	Students follow 3.B.2 and list observations.
	Step 5.	Discuss observations from 3.B.2.
	Step 9.	Students answer questions in 3.B.2. (Assign R.A.S. Chapter 28; page 126).
Period 3 -	Step 1.	Vocabulary: point source, broad source.
	Step 2.	Read and discuss 3.C.1.
	Step 4.	Students follow 3.C.1 and make diagrams and answer questions as directed in the text.
	Step 5.	List observations on the blackboard and discuss.
		Vocabulary: umbra, penumbra. (Assign R.A.S. Chapter 30; page 132).
Period 4 -	Step 1.	Define the purpose of 3.C.2: To see what happens when light from a candle passes through a pinhole and strikes a screen.

Step 3. Do not refer to the text at this point. Ask students to predict (using a diagram) what they will see on the screen.

Step 4. Tell students to experiment with the apparatus and make as many observations as possible.

Step 5. List all observations on the blackboard and discuss.

Step 6. Have students draw a ray diagram to explain the observations.

Step 9. Students answer 3.D, questions 1, 2, 5.

Period 5 - Begin Section 4: Reflection.

Purpose: To study reflection by a plane mirror.

Step 1.(a) Vocabulary: plane.

(b) Define the purpose of this section.

Step 4. Students follow 4.A.1.

Step 5. Discuss observations from 4.A.1.

Step 1.(c) Teach students the use of a protractor. Use a worksheet for practice in measuring, naming and constructing angles.

Period 6 - Step 2.(a) Read and discuss 4.B.1.

(b) Vocabulary: normal, perpendicular, right angle, incident ray, reflected ray, angle of incidence, angle of reflection.

Step 4. Students follow 4.B.1.

Step 5. Discuss results of 4.B.1.

Step 6. Students make a written conclusion for 4.B.1.

Period 7 - Step 1. Define the purpose of 4.B.2.

Step 2. Read and discuss 4.B.2.

Step 3. Students predict where the image will be found.

Step 4. Students follow 4.B.2.

Step 5.(a) Discuss the results of 4.B.2.

(b) Vocabulary: virtual and real images (see 4.C.1).

Step 6. Compare results with predictions and complete a ray diagram showing how the image is located.

Step 9. Students answer questions in 4.B.2.

Period 8 - Step 1. Define the purpose of 4.B.3: To see how light reflects from different types of surfaces.

Step 2. Read and discuss 4.B.3.

Step 4. Students follow 4.B.3 and record observations.

Step 5. List observations on the blackboard and discuss.

Step 6. Compare the different types of surfaces and define diffuse reflection.

Step 9. Students answer questions in 4.B.3.

Period 9 - Step 1. Define the purpose of 4.C.2: To see how many images are formed by two mirrors set at various angles.

Step 2. Read and discuss 4.C.2.

Step 3. Students design a data table to record the angles they are to test, the predicted number of images and the observed number of images.

Step 4. Students follow 4.C.2 and record observations.

Period 10 - Step 5. List results from all groups on the blackboard.

Step 6.(a) Discuss the results and compare the discrepancies between groups.

Step 7. Discuss the procedure and have students suggest any improvements.

Step 8. Students perform the experiment again making use of suggested improvements.

Step 6.(b) Compare class results with the predictions. Ask students to find a relationship between the number of images, the number of degrees in a circle, and the angle between the mirrors.

Period 11 - Step 9. Students answer question in 9.D, nos. 1, 3, 4, 7, and 8. Students may make use of equipment if necessary to test their answers.

Period 12 - Begin Section 5: Curved Mirrors.

Purpose: To study reflection by curved mirrors.

Step 1.(a) Define the purpose of this section.

(b) Vocabulary: convex, concave, cylindrical.

Step 4.(a) Students follow the first part of 5.A.1 (looking into convex and concave mirrors and describing the image at various distances.)

Period 13 - Step 1.(a) Vocabulary: aperture.

Step 2. Read and discuss 5.B.1.

Step 4. Students follow 5.B.1 and record observations.

Step 1.(b) Vocabulary: centre of curvature, principal axis, focal point, principal focus, focal length, radius of curvature.

Step 5. List observations on the blackboard (diagram)

Step 6. Discuss angles of incidence and reflection and make a conclusion about reflection from the curved mirror.

Step 9. Students answer questions at the end of 5.B.1.

Period 14 - Step 1.(a) Vocabulary: spherical concave mirror.

(b) Discuss 5.A.1 (the need for a "bundle"of parallel rays and the way to obtain these.

(c) Define the prupose for 5.B.2.

Step 2. Read and discuss 5.B.2.

Step 4. Students follow 5.B.2 and record observations.

Step 5. Discuss observations and compare the measurements of the focal length.

Step 6. Review the direction of reflection of a ray parallel to the principal axis, and a ray through the principal focus.

Period 15 - Step 1.(a) Define the purpose of 5.A.3.

(b) Review as in step 6 above.

Step 2. On the blackboard draw the diagram as in 5.A.3 and show students how to predict the position of the image at position C. Describe the image expected.

Step 3. Students draw a series of diagrams for positions B, C, A, and F to predict the image. Describe each image.

Period 16 - Step 1. Define the purpose of 5.B.3.

Step 2. Read and discuss 5.B.3.

Step 3. Students design a data table to record the position of the source, the predicted position of the image and the actual position of the image.

Step 4. Students follow 5.B.3.

Step 5. Compare class observations and compare these with the predictions.

Step 9. Students answer the questions at the end of 5.B.3.

Period 17 - Step 2. Read and discuss 5.C.1.

Step 3. Students predict the position of the image as in 5.C.1.

Step 4. Students test their prediction.

Step 5. Discuss the results of 5.C.1.

Period 18 - Step 1. Define the purpose of 5.C.2.

Step 2. Read and discuss 5.C.2.

Step 4. Students follow 5.C.2 and try to find the focal length of a convex mirror.

Step 5. Discuss the results of 5.C.2.

Step 9. Students answer questions 2, 3, 5 in 5.D.

Period 19 - Begin Section 6: Refraction.

Purpose: To study light passing from one transparent substance to another.

Step 1. Define the purpose of section 6.

Step 4.(a) Students follow 6.A.1 and list observations.

Step 2. Read and discuss 6.B.1.

Step 4.(b) Students follow 6.B.1 and list observations.

Step 9. Students answer questions at the end of 6.B.1.

Period 20 - Step 1.(a) Vocabulary: medium, refraction.

(b) Define the purpose of 6.B.2.

Step 2. Read and discuss 6.B.2. part 1 (a) only.

Step 4. Students follow part 1 (a) of 6.B.2.

Step 5. Discuss observations from 6.B.2.

Vocabulary: refracted ray, angle of refraction.

Step 9. Students answer questions at the end of part 1 (a) of 6.B.2.

Period 21 - Step 1. Define the purpose of 6.B.3.

Step 2. Read and discuss 6.B.3.

Step 3. Students design a data table to record angle measurements.

Step 4. Students follow 6.B.3.

Step 5. Discuss and compare observations from 6.B.3.

Step 6. Students make a conclusion about the way light bends at an interface.

Period 22 - Step 2. Read and discuss 6.C.2.

Step 4. Students try to answer (using diagrams) the questions asked in 6.C.2.

Step 5. Discuss observations from 6.C.2.

Step 9. Students answer questions 1, 2, 5, 7 in 6.D.

Period 23 - Begin Section 7: Lenses.

Purpose: To study the passage of light through lenses.

Step 1. Define the purpose of this section.

Step 4.(a) Demonstrate 7.A.1 and have students make observations by making a diagram.

Step 2. Read and discuss 7.B.1.

Step 4.(b) Students follow 7.B.1 and make observations.

Period 24 - Step 5. Discuss observations from 7.B.1. Review vocabulary: principal axis, aperture, focal point, principal focus, focal length, converge, diverge.

Step 9. Students answer questions in 7.B.1.

Step 1. Define the purpose of 7.B.3.

Step 2. Read and discuss 7.B.3.

Step 3. Students design a data table to record all measurements.

Step 4. Students follow 7.B.3 (use two lenses).

Step 6. Compare results of different groups for each lens.

Period 25 - Step 1. Define the purpose of 7.B.4.

Step 2. Read and discuss 7.B.4.

Step 3. Students design a data table to record observations for 7.B.4.

Step 4. Students follow 7.B.4 and record observations.

	Step 5.	Discuss and compare observations from 7.B.4.
	Step 9.	Students answer the questions at the end of 7.B.4.
Period 26 -	Step 1.	Define the purpose for 7.C.2.
	Step 2.	Read and discuss 7.C.2.
	Step 4.	Students follow 7.C.2 and record all observations.
	Step 5.	Discuss observations from 7.C.2.
	Step 6.	Students answer the questions in 7.C.2.
Period 27 -	Step 9.	Students answer questions 1, 2, 5, 6, 10 in 7.D. Students may use apparatus to test their ideas if necessary.