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The Effects of Identified Student Characteristics on Their Understanding of Science

Patricia Mutch Cheeseman

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THE EFFECTS OF IDENTIFIED STUDENT CHARACTERISTICS
ON THEIR UNDERSTANDING OF SCIENCE

BY

PATRICIA MUTH CHEESEMAN

A thesis submitted
in partial fulfillment of the requirements for the
degree of Master of Science, Major in
Biology, South Dakota
State University

1972
THE EFFECTS OF IDENTIFIED STUDENT CHARACTERISTICS
ON THEIR UNDERSTANDING OF SCIENCE

ACKNOWLEDGMENTS

A research study such as this one is dependent upon the cooperation and help of many people. The author wishes to express gratitude to Dr. Donald A. Myers, major advisor, who has provided suggestions, encouragement and most needed help during all stages of research and writing. A special thank you is given to Dr. W. Lee, whose statistical help was invaluable in completing this project. Thanks are also extended to Barry L. Jones, the statistical consultant. This author collaborated during the selection and development of data and assimilation of results.

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

Head, Botany-Biology Department
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A research study such as this one is dependent upon the cooperation and help of many people. The author wishes to express gratitude to Dr. Gerald A. Myers, major advisor, who has provided suggestions, encouragement and most needed help during all stages of research and writing. A special thank you is given to Dr. W. Lee Tucker for providing the statistical analysis and for guiding the author in interpretation of the data. The author is most grateful to Brookings Middle School, Huron Junior High School and Mitchell Junior High School students, teachers and administrators for their parts in supplying data. Thanks are also extended to Curtis J. Johnson, with whom this author collaborated during the selection and development of testing instruments, and during the evaluation and assimilation of data.
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CHAPTER I

INTRODUCTION

The earth continues to rotate on its axis at about the same rate as it has for uncounted centuries, but the pace of its human occupants is ever accelerating. Not only do we travel faster and live longer, but we are faced with an ever-multiplying body of scientific knowledge available for our use. Children are called upon to master more skills -- earlier than ever before. Today's educators must consider a basic philosophical question: Should public schools teach scientific content or processes, the timely or the timeless? And, having chosen a curriculum, they ask how it can be used most effectively. Some public schools have decided to depart from the traditional presentation of facts by the teacher to a new classroom situation where the student takes the more active role and the teacher functions more as a consultant and guide. The teacher's role then is as a facilitator of learning, providing the resources and a climate conducive to critical thinking.

The three South Dakota schools which have contributed information to this study were Brookings Middle School, Huron Junior High School, and Mitchell Junior High School. These schools have chosen the Intermediate Science Curriculum Study (ISCS) course which was developed by Florida State University, Science Education Department, and was financed in part by the U. S. Department of Education, and the National Science Foundation.
The ISCS is published by the Silver-Burdett Publishing Co., a division of General Learning Corporation. Working with Silver-Burdett is the Educational Division of Damon Engineering as manufacturer and supplier of laboratory material needed for ISCS. The seventh grade, which is designated as ISCS Year I, is followed in all three schools by the eighth grade course which is designated as Year II. Only Year I students took part in this experiment.

**STATEMENT OF THE PROBLEM**

This study was undertaken to try to identify which factors most influence the process of learning science in an ISCS Year I classroom. Because of the breadth of the subject, it has seemed desirable to limit the factors to be considered to those which could be termed "characteristics" of the students. Therefore, recognizing the fact that characteristics alone cannot present the whole picture, occasional mention will be made of other contributing elements. It should be understood that only the characteristics to be named in a later section were included in the statistical analysis.

**Null Hypothesis**

It was expected that no specific student characteristic would be indicated to account for the variance in student scores between the pretest and the posttest of the Sequential Test of Educational Progress (STEP).

**Importance of the Study**

It was hoped that the findings of this study would be helpful to
educators considering future curriculum changes. Assuming the testing measures to be adequate, this study might be used to indicate which factors were the most influential in the learning of science; and being aware of this information, educators might then determine how these factors could be influenced in order to further facilitate the learning process. This study might suggest future studies and indicate the adequacy or inadequacy of present standardized testing instruments in junior high school level science courses.

The Research Design

This was a time-series experiment where the subjects underwent repeated measurements both before and after the introduction of the treatment. The treatment, ISCS Year I, was the constant variable. The research design could be diagrammed in the following way:

\[ O_1, O_2 \times O_3, O_4, O_5, O_6 \]

The first test given was the Sequential Test of Educational Progress, hereafter referred to as STEP 3A. It is designed to measure general science knowledge of secondary school pupils in grades seven, eight and nine. The STEP 3A was represented by \( O_1 \), a pretest. The next instrument used was the Student Opinionnaire. The same form of the Student Opinionnaire was used for both pretest and posttest. The pretest Student Opinionnaire was designated as \( O_2 \). The experimental treatment, ISCS Year I, was represented by the symbol \( X \). Both \( O_1 \) and \( O_2 \) were administered during September 1970 and ISCS Year I was taught during the school year from September, 1970 to June, 1971. Following the experimental treatment, the posttest STEP 3E
shown as $O_3$, and the posttest Student Opinionnaire, shown as $O_4$, were administered during the last two weeks of March, 1971. Element $O_5$ represents the Teacher Opinionnaire and $O_6$ represents the School Administrator Opinionnaire. These instruments were completed by the seventh grade science teachers and the school administrators of the participating schools during February, 1971.

THE TESTING INSTRUMENTS

The Sequential Test of Educational Progress

After examination of many standardized tests, the researchers decided to use the STEP because it has test forms specifically for general science knowledge for grades seven, eight and nine. There are two equivalent forms based on the same scale. Questions were not aimed at the specific objectives of ISCS. To the knowledge of the researchers, there does not exist at this time a validated standardized test for the specific objectives of ISCS. These objectives would include use of the metric system, behavioral objectives, operational definitions and laboratory techniques.

Following is a description of skills tested by STEP. These are categories according to which the items were classified by Philip G. Johnson, Cornell University, and Frank J. Fornoff, Educational Testing Service (11):

**Ability to identify and define scientific problems.**
Included in this category is the ability to isolate a problem from a mass of given material and formulate the problem in a way which allows for systematic solution.

**Ability to suggest or screen hypotheses.**
Subabilities included here are the relationships, abilities to suspend judgement, recognize cause-and-effect relationships, recognize the logical consistency and plausibility of a hypothesis, and to select the principle applicable to a given situation.
Ability to select valid procedures. This encompasses the design of experiments and the planning required for collection of appropriate data.

Ability to interpret given information and draw conclusions. This includes the ability to formulate valid conclusions and to recognize or draw valid generalizations from data known or given.

Ability to evaluate critically claims or statements made by others. This encompasses the critical evaluation of advertisements, written materials, and audio-visual materials. Other abilities included are the abilities to detect superstition and extrapolations and generalizations; to distinguish fact, hypothesis, and opinions; and to distinguish the relevant from the irrelevant.

Ability to reason quantitatively and symbolically. Included under this heading are abilities to understand and use numerical operations, symbolic relations, and information presented in graphs, charts, maps, and tables.

Subject matter tested is from the following sciences: biology, chemistry, physics, astronomy, geology and meteorology. Since the tests in STEP are intended primarily as measures of developed abilities in six broad areas of education, their content validities (10) are of primary importance. According to Robert W. Mayer, the Psychological Examiner who conducted the validity study in 1958,

Content validity is best insured by relying on well-qualified persons in constructing the tests, as was done for the STEP series. . . Empirical checks have been made relating test scores to suitable criterion measures. . . This study attempted to evaluate the relationship between SCAT-STEP scores (SCAT refers to School and College Ability Tests) and school grades in an unselected sample of 271 seventh grade students in the Newark Central Junior High School. In addition, SCAT-STEP scores were studied in relation to WISC (Wechsler Intelligence Scale for Children) results in a sample which included 100 of the above students. . . Moderate and substantial correlations were found between scores on STEP tests in Writing, Mathematics, Science and Social Studies when correlated with grades in corresponding school subjects. . . WISC full-scale results were correlated with average school grades and a high, marked relationship was noted.

For further information regarding the validation of STEP, refer to the 1958 SCAT-STEP Supplement (10).
Reliabilities have been reported for the six STEP tests. They were the result of internal analyses based on single administrations of the tests, and are estimates of consistency. Correlations between scores on alternate forms or between test-retest scores have not been obtained. It was stated in the STEP Technical Report, Number Five (12) that,

For each test, reliabilities were estimated for four samples tested in the norms program. Analyses were done separately for grades five, eight, eleven and thirteen. Only the A forms were analyzed; however, the results should characterize the B forms reasonably well, since the A and B forms were very similar in content. . . Kuder-Richardson Formula 20 was used to estimate all of the reliabilities and standard errors of measurement.

The reliability estimates vary somewhat from test to test. The median reliability for Science is .89.

Student Opinionnaire

The first half of the Student Opinionnaire, Appendix A, was devised by the researchers especially for this study. Questions were chosen to indicate the degree of interest in science, feelings toward teachers, willingness to take part in small-group discussions, and manual dexterity. The last fifteen questions were taken verbatim from, "An Independent Evaluation of Seven Elementary and Junior High School Science Projects," by Dr. Adrian N. Gentry (1). They were designed to indicate the student's evaluation of the ISCS course of study. A tendency to go toward a lower number on the multiple choice answers indicated a change to a more positive attitude toward science from the pretest to the posttest for all opinionnaire questions, except for those questions which indicated such things as choice of laboratory partner, and preference of individual or team activities.
Teacher and School Administrator Opinionnaires

The two instruments were of similar construction, with some rewording. The first 11 questions supply characteristics such as age, sex, college hours in science, attitude toward science, degrees earned, teaching experience and other work experience. The section from question 12 through 31 were taken verbatim from "Scales for the Measurement of Attitudes," by Marvin E. Shaw and Jack M. Wright (13). These questions are designed to express attitudes toward education and they have been validated and tested for reliability. For further information refer to pages 82 through 86 of the work cited above. Questions 32 through 41 were especially designed by the researchers to show preference for a style of teaching and an inclination toward either the traditional, expository-direct method, or the innovative inductive-indirect method. Teacher Opinionnaire and School Administrator Opinionnaire results were not included in the statistical analysis, but were referred to as supplementary information. They have been included in this study as Appendices B and C.

LIMITATIONS OF THE STUDY

The experimental group was limited to the seventh grade science classes. A total of 548 students, seven teachers and nine school administrators from Brookings Middle School, Huron Junior High School and Mitchell Junior High School cooperated by taking tests and/or completing opinionnaires. These schools were similar in size, teacher-pupil ratio, socio-economic level, racial make-up and range of I. Q. The study was further limited to the school year beginning approximately September 1, 1970, and ending approximately May 30, 1971.
DEFINITION OF TERMS

The following terms have been explained in order that specific connotations would be understood by the reader:

_**Characteristics**_ of students are those conditions peculiar to an individual student. They are conditions over which he has little or no control, such as sex, intelligence, socio-economic level, teacher assignment or classroom conditions.

_**Process approach**_ is a type of curriculum designed to provide the student with insights of scientific procedures for gaining new knowledge.

_**Inductive-indirect teaching**_ focuses on the student rather than the teacher. The student conducts investigations and is guided to the desired conclusion by asking questions and by the use of observations and inferences.

_**Expository-direct teaching**_ is also referred to as the traditional method. The authoritarian position of the teacher as a lecturer is emphasized. Student activities including listening, reading, answering questions and discussion of the lesson are under the direct control of the teacher.
CHAPTER II
SOME PERTINENT LITERATURE

Many American educators have given careful study to the process approach to the teaching of science. The objective has been to discover and put into practice better methods of imparting the skills and knowledge of physical science to the rapidly moving new generation, and to encourage an improved student attitude toward the study of science. Paul Hounshell and Erwin L. West, Jr., (4), have expressed some ideas concerning this trend in the following remarks:

In years past, the focus of education was on facts, but it has become evident that knowledge of vast reservoirs of facts, while beneficial, it not necessary. Particularly is this true since today's "facts" in science may be tomorrow's falsehoods, and since past and current knowledge may now be stored in an electronic brain. The trend today is to utilize man's capabilities as a thinker and to encourage him to seek the answers to the "why" behind the "what". In other words, science should be taught as an intellectual pursuit.

It is desirable to start formulating correct scientific methods from the first contact that a student has with science. Among the many new programs developed, using various educational philosophies, one program developed by the American Association for the Advancement of Science's Commission on Science Education, named "Science -- A Process Approach", has been used successfully in the elementary schools. Ideally this introduction prepares a student well for process approach learning in subsequent science studies. In reference to Science -- A Process Approach, Louise Y. George (2) states:
The process approach has in it a little of both the 'content' and the 'creativity' approaches. Though it rejects concentration on any particular science, it extends the notion of teaching generalizable ideas and skills. While it rejects the notion of 'creative ability' as a highly general trait, it adopts the idea that productive thinking can be encouraged in relation to each of the processes of science -- observing, inferring, communicating and so on. The argument is that if transferable intellectual processes are to be developed in the child for application to continued learning in science, these must be separately identified, learned and otherwise nurtured in a systematic manner. It is not enough to be creative 'in general' -- one must learn to be thoughtful and inventive in observing a variety of specific phenomena, in manipulating many different objects in space and time, in predicting a number of kinds of events, as well as in producing hypotheses.

The child who has learned science processes in this manner should be capable of studying science in the higher grades in a way which is not now possible. It seems probable that such a student will be able to learn about any given science, presented in accordance with its theoretical structure, in far less time than would otherwise be required. Certainly he should have a better conception of science as a way of thinking and discovering.

The ISCS project has attempted to provide a practical and workable strategy enabling junior high school teachers to individualize instruction. Individualization of instruction has long been an objective in science teaching. This self-paced, laboratory-oriented course gives the student opportunity to be increasingly creative and self-directed. The teacher thus freed from group instructional techniques is able to meet his students on a one-to-one basis with greater flexibility.

The fundamental assumption underlying the ISCS curriculum plan (5) is that science at the junior high school level should serve a general educational function for all students. To quote from the Teacher's Manual:
Considerable debate has arisen recently whether techniques (process) or scientific inquiry or concepts of science provide the better basis upon which to organize instructional materials. The ISCS program presumes that these important aspects of science can and should be introduced simultaneously by allowing major concepts to arise out of student investigation... The concepts included in the seventh grade materials cannot be claimed to 'cover' any branch of science, nor are they comprehensive of all topics that might logically be related to the energy theme. Fundamental to the ISCS approach is the belief that exploring in depth a small area of powerful, well-integrated content leads to better understanding than superficially passing over a large volume of information. We felt that a reasonable understanding of the concepts dealt with is a powerful tool for the student in understanding the environment and that the student so equipped and able to use the included process skills is in an excellent position to progress not only in grades eight and nine, but in whatever he does beyond that point.

The innovative methods of individualization, process approach and inductive-indirect teaching go hand-in-hand, although they are not synonymous. In his Master's thesis, George Heaton (3) states:

Students need more time to interact; most classrooms find teachers talking, rather than students interacting; methods need to be established to insure a great deal of student active involvement... The Association of National Advertisers states people retain only 20% of what they hear, 50% of what they see and hear, but 70% of what they say. What this means is that a tremendous amount of learning takes place when youngsters have an opportunity to talk.

Where interaction among students is allowed, a most valuable result is that of peer teaching. In a random distribution of students, or even if the students are allowed to choose their own laboratory partners, it frequently happens that the two partners are not of the same ability. The benefit to a non-reader by having a competent reader for a partner is obvious. The more subtle advantages which may exist are the opportunity to consult, availability of help in procuring supplies and help in setting up experiments. These things would be
difficult in a science classroom where silence was taken to be a sign that learning was taking place and that the teacher was in full control. Following is a quotation from "The Open Classroom" by Herbert R. Kohl (8):

The classroom not only segregates young people from society, it segregates them from each other... Not only do we not let children of the same age teach each other by insisting upon silence in the classroom, we make it impossible in the context of school for older children to teach younger ones... An open classroom with many activities going on simultaneously is not a silent place. Students talk to each other. They also talk to the teacher and move around from group to group. The noise in the classroom is not harsh or hysterical, but it often fills the room and can upset other teachers who insist upon silence in their rooms.

It has been observed in ISCS classrooms that students become progressively more self-directed and purposeful in their investigative activities. Those students who have never had the opportunity or have not yet learned to read carefully, think independently or make decisions as to the procedures to follow find they fall behind their classmates who effectively follow the lesson instructions. With guidance from the teacher they, too, can improve their use of time and energy and proceed in a purposeful manner. In a paper presented at the National Association for Research in Science Teaching, David Vitarogan (15) states as follows:

When pupils are self-directed, the teacher's role changes drastically. The teacher's role in implementing a Science Skills Center is one of arranging the conditions conducive to learning by structuring a classroom in which learning can take place. This involves such activities as teaching the pupil how to teach himself, insure success by carefully matching materials to needs, diagnosing, guiding, interpreting and evaluating growth as a service to the pupil and not as a judgment. The teacher, in such a setting, is also involved in supplying on-the-spot first aid when materials do not
work or when they are unavailable, develop new materials to solve problems and personally interact with small groups and individually.

Where students and teachers are interacting silence cannot obtain. Noise cannot be eliminated, but it can be modulated. The effect of distraction is not fully understood, but it is being investigated. In a recent article by John P. Keating and Timothy C. Brock (7) the following comments appeared:

Our experiment incorporated the distraction task as an integral part of the experimental manipulation and did not attempt to manipulate the comparative importance of either the distraction or the communication. We felt that this was more true to life: distraction normally is something that impinges on our awareness without demanding direct attention. In either case, however, when the subject is paying attention to the communication while he is simultaneously being distracted, the communication becomes more persuasive...

We began this paper with reflections on the physical environment that seemed essential to carry on serious concentration. Silence and seclusion have been thought to be the sine qua non of concentration, and distraction anathema to any serious attempts at real thought. While this may be true in many instances, we believe that our present research offers data that should caution us against an over generalization of this postulate.

The effects of distraction would constitute a study in its own right and doubtless many researchers could be quoted on either side. Also, the many facets of student behavior must play a part in the learning process. Some students measured by the Student Opinionnaire, previously described on page seven, have been studied and evaluated by Curtis J. Johnson, who collaborated with this writer. The specific results of his study may be found in his Master's thesis (6), entitled "The Effects of Identified Student Behaviors on Students' Understanding of Science."
As a measure of academic achievement, the three participating schools all employ the Iowa Tests of Basic Skills (ITBS). The fundamental areas of vocabulary, reading, the mechanics of correct writing, methods of study and arithmetic are tested in this way each year. There is at this time no test of science achievement included in the ITBS test battery. As stated in the ITBS Teacher's Manual (9), the purposes of the tests are to reveal how well each pupil has mastered the basic skills. Other general ways in which this information can be used are: as an aid in fitting instruction to the needs of individual pupils; as an aid in improving pupil guidance, particularly in the upper grades; as an objective, reliable supplement to course grades based on classroom work; as a measure of pupil growth from year to year; and as the means of learning how pupils in one school compare with those in other schools. The ITBS Teacher's Manual (9) also states:

The content of each test has been very carefully selected to reflect the best of current curriculum practices. Only items of appropriate difficulty (as shown by preliminary tryouts) have been assigned to each grade level. The arrangement of the various tests has been organized into a logical pattern that yields tests of uniform length and reliability.

For instance, a grade equivalent composite score of 71 indicates the student performed as well as the average student would during the first month of the seventh grade.
CHAPTER II
STATISTICAL DESIGN

The dependent variable was the change of score from the STEP 3A to the STEP 3B (Y). The independent variables studied were as follows:

(X₁) the grade equivalent composite score for each student on the ITBS;

(X₂) the intelligence quotient as measured by either the Lorge-Thorndyke or Otis tests;

(X₃) the teacher to whom each student was assigned;

(X₄) the sex of the student;

(X₅) the age of the student and

(X₆) the grade received in science. Variables X₇ through X₃1 were items in the Student Opinionnaire (See Appendix A).

The Iowa tests were administered to the subjects during September, 1970. The intelligence tests were administered during October, 1970. It is recognized that the Otis scores will generally rate the same student a few points higher than the Lorge-Thorndyke, but for the purposes of this experiment, the difference was considered to be unimportant. The teacher of each class was given a number arbitrarily to associate the students with others who had the same teacher.

The data consisted of 548 students from the three aforementioned schools for whom both a pre- and post- STEP and a pre- and post-

Student Opinionnaire were available. The variables appear in the order entered into the equation in Table I on page 18. The items of information analyzed were the change from pretest to posttest.
Dr. W. Lee Tucker, Experiment Station Statistician, South Dakota State University (14), multiple regression was the technique which could best be utilized to analyze the data since it was desired to determine how much change in the dependent variable (STEP) could be explained by the various independent variables. An electronic computer was utilized to facilitate speed and accuracy. The variable means and simple correlations were obtained in addition to the multiple correlation between the dependent variable and the independent variables. The independent variables were entered into the equation in the order of their importance along with the amount of variability in the dependent variable explained. For example, variable $X_3$ (teacher) explained 5% of the total variability of $Y$ (change of pre- and post- STEP). The error mean square, obtained from the unexplained variability of the dependent variable was used to determine which independent variables explained a significant part of the variability of the dependent variable.
CHAPTER IV
RESULTS

Of the total number of 548 subjects, 50.4% were boys and 49.6% were girls. Their mean age was 11.92 years; their mean grade equivalent on the ITBS was 78 and their mean I.Q. composite score was 109.26. The mean change in STEP test score was .83. The mean score of the STEP 3A was 32.10 questions correct out of a possible 60 questions, and the mean STEP 3B score was 32.93 questions correct out of a possible 60 questions. This may be compared with the validated mean of STEP 3A of 31.93. Of the 31 independent variables, it was found that only 10.7% of the variance could be accounted for and that the two most influential variables accounted for seven percent of the total variance. (See Table I)

The most influential variable was the teacher. This single factor accounted for five percent of the total variance and was significant at the .05 level of confidence. The second most influential variable was determined to be the ITBS grade equivalent. The ITBS had an average value of 78 with a standard deviation of 13.99. This indicated the mean level of achievement was at the eighth month of the seventh grade. The performance on the ITBS accounted for two percent of the total variance, which also was significant at the .05 level. The third most influential variable was the age of the subjects, but this was found to be insignificant at the .05 level.
<table>
<thead>
<tr>
<th>Variables Listed in Order they were entered into equation:</th>
<th>Mean</th>
<th>Sum of Squares Reduced in this step</th>
<th>Proportion Reduced in this step</th>
</tr>
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<tbody>
<tr>
<td>Step No.</td>
<td></td>
<td></td>
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<tr>
<td>(X₃) 1. Teacher</td>
<td></td>
<td></td>
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<tr>
<td>(X₁) 2. ITBS grade equivalent</td>
<td></td>
<td></td>
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<tr>
<td>(X₅) 3. Age</td>
<td></td>
<td></td>
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<tr>
<td>(X₄) 4. Sex (0 = girls, 1 = boys)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(X₁₀) 5. Grade in Science</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(X₂) 6. I.Q. composite</td>
<td></td>
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Remaining 25 steps
Total Sums of squares reduced:
Grand Total Sums of Squares:
Proportion not accounted for:

* Variables found by multiple regression to be significant at the .05 level of confidence.

Equation used: \[ Y = a + b₁ X₃ + b₂ X₁ = 49.827 - .842 X₃ - .073 X₁ \]

Y = The change in score on STEP from 3A to 3B, the dependent variable.

X = The independent variables.

a = Intercept.

b₁ = Regression coefficient of X₃.

b₂ = Regression coefficient of X₁.
CHAPTER V
DISCUSSION

The importance of the teacher, which is the most influential variable, may be viewed in several ways. In the inductive-indirect approach to teaching one might look for a decline in teacher impact, or a lessening of teacher control. Indeed when the casual visitor views an active group of students engaged in diverse activities, and hears a good deal of verbal communication, he might wonder if the students were following a plan at all. The lack of regimentation, within certain limits, is actually more conducive to creative study than is the rigidly structured classroom situation. (7) It is possible that the teacher is much better able to communicate on the one-to-one basis which obtains in an ISCS laboratory classroom. While some students are able to go ahead independently and call upon the teacher only as the need arises, other students may need special encouragement or explanation frequently. Only a truly flexible program can best serve all students. It may help students to view themselves as worthwhile individuals when class progress is not uniform or dictated by either slow, moderate, or fast workers, or set arbitrarily by the teacher.

Pupils are encouraged to move along as rapidly as their understanding of the work will allow. They are cautioned against careless haste which would diminish the value of the experiments. The course challenges the teacher to meet each student at his level, and to lead
him to discover for himself the concepts involved in his particular experiment. This necessitates much flexibility to go from Chapter 3 at one table to Chapter 10 at another table.

Another relationship to consider is the performance variation among classes and among schools. This variation indicates a greater gain for students of teachers to whom lower numbers had been assigned. (See Table II below.) This variation in gain is not well understood, but there are some plausible explanations. By calculating the mean scores of the STEP 3A for each teacher it was apparent that the classes of those teachers to whom lower numbers had been assigned also generally received lower mean scores.

**TABLE II**

**STEP 3A MEAN SCORES LISTED BY TEACHER NUMBERS**

<table>
<thead>
<tr>
<th>Teacher Number</th>
<th>STEP 3A Mean Score</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28.2</td>
<td>.91</td>
</tr>
<tr>
<td>2</td>
<td>27.9</td>
<td>.97</td>
</tr>
<tr>
<td>3</td>
<td>29.5</td>
<td>.93</td>
</tr>
<tr>
<td>4</td>
<td>33.4</td>
<td>.89</td>
</tr>
<tr>
<td>5</td>
<td>32.4</td>
<td>.93</td>
</tr>
<tr>
<td>6</td>
<td>32.7</td>
<td>.88</td>
</tr>
<tr>
<td>7</td>
<td>33.8</td>
<td>.96</td>
</tr>
</tbody>
</table>

When arranged according to teachers, the mean STEP 3A scores ranged from 28.2 to 33.8. The overall mean was 32.1. Classes which started with lower mean scores, however, showed more gain in the STEP 3B than did those who began with a higher mean score. To carry this observation further a check was made of the teacher and school
administrator opinionnaires. While the teacher's answers were very similar, there was a marked difference in administrative responses which referred to attitude toward science. These administrative responses seemed to coincide with the respective student mean scores on STEP 3A. The pretest, of course reflects the student's exposure to science up through grade six, prior to ISCS in grade seven, and logically indicates the importance placed on science in elementary school. This might reflect the attitude of the school administration toward science in the elementary grades.

Another possible explanation of the greater gain might be the so-called Hawthorne Effect, which is exhibited by groups knowing themselves to be experimental. It is a conscious or unconscious over-achieving by members of a group because they are "special" and feel special. The classes which did show the greatest gain were in the school which most recently adopted ISCS science in the seventh grade.

The factor labeled "teacher" then is an aggregation of many influences. The teacher designation of one through seven (See Table II), links each student with a teacher, a classroom, and a school system. Physical conditions such as temperature, lighting, seating arrangements and distractions along with other unmeasured variables are also included in this single factor. A continuing study of all groups involved in this experiment would be interesting and perhaps revealing; but at present there are no plans for such a continuation.

In view of the gain, .83, shown by the mean posttest score (STEP 3B) over the mean pretest score (STEP 3A), it seemed that ISCS
does help a student to do better on a standardized test in general science. The mean score of the schools involved, 32.1, does compare favorably with the validated mean score of STEP 3A which was 31.9.

Influence of the ITBS grade equivalent score over the change in score on the STEP achievement tests indicated that students who possess the basic skills to perform at a high degree of achievement also have the ability to profit from their experience in ISCS courses. This was more meaningful perhaps when one considered that the I. Q. scores were not significant at the .05 level of confidence. (See Table I)

The null hypothesis was rejected, as it was determined by multiple regression that certain student characteristics were significantly influential at the .05 level of confidence. These characteristics were the student's teacher and the student's grade equivalent on the ITBS.
CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A scientific experiment should result in three things: It should (1) provide descriptions of observations; (2) allow predictions to be made and (3) suggest future experiments. In consideration of the results of the tests and analyses, the following conclusions were made:

Of prime importance was the teacher as a factor in the student's learning of science. This places the classroom situation as the most important. Figuratively, in this "crucible" we find blended a student's feeling of ease or ill-at-ease; his acceptance or rejection; his receipt of encouragement or discouragement; the teacher's security or insecurity; the administration's emphasis or de-emphasis on science at this and earlier grade levels. These influences are extremely difficult to separate and scrutinize, but they are of significant importance.

Of secondary importance was the student's performance on the ITBS as indicated by the mean composite grade equivalent rating. A significant correlation was found to exist between performance on the ITBS and the amount of improvement by students on the STEP 3B over the STEP 3A. Knowing the relationship of ITBS scores to STEP scores enables one to predict the future performance in science on the basis of the ITBS tests with a low degree of positive correlation.

A need for improvement was indicated by the lack of adequate standardized tests for process approach science courses. While the
mean scores of all schools involved compared favorably with the validated means, much of the process and content of ISCS was not tested at all by either STEP or ITBS. It is believed that students who performed this well on standardized tests, and were not even tested on the bulk of their science work, could conceivably perform a great deal better on a more comprehensive test.

Another area which needs further study is that of the main objective of this study, i.e., to identify the strongly influential factors in science learning. All of the factors studied here could account for only 10.7% of the total variance. The other 89.3% remains unexplained. The possibility exists that herein lies a vast, unexplored area in which students could be helped, unless these factors are too nebulous ever to be identified. This is a challenging problem.
SELECTED REFERENCES


APPENDIX A

STUDENT OPINIONNAIRE -- Part 1

Record your answers on the answer sheet as instructed.

1. How interested would you be in taking a course in science if it were not required? B 2-h*
   A. Very interested.
   B. Somewhat interested.
   C. I don't care one way or the other.
   D. Not too interested.
   E. Not at all interested.

2. How interested are you in learning more about science? B 2-h, g
   A. Very interested.
   B. Somewhat interested.
   C. I don't care one way or the other.
   D. Not too interested.
   E. Not at all interested.

3. I find the subject of science to be B 2-h, g
   A. very interesting.
   B. somewhat interesting.
   C. somewhat uninteresting.
   D. very uninteresting.

4. The last grade I received in science was C 2-e
   A. A.
   B. B.
   C. C.
   D. D.
   E. Incomplete or failing.

* Code numbers for use by evaluators.
5. I consider my last year's science teacher as
   A. very well qualified.
   B. somewhat qualified.
   C. not too well qualified.
   D. poorly qualified.

6. My favorite subject is
   A. Science.
   B. Language.
   C. Health and P.E.
   D. Math.
   E. Social Studies.

7. In science class I would rather
   A. work by myself.
   B. work with one other person.
   C. work with 3 to 5 other people.
   D. work in a group of 6 to 15 people.
   E. work as a member of a class of 15 or more people.

8. For a lab partner in science I would prefer a
   A. boy.
   B. girl.

9. In a group discussion (among students) I would prefer
   A. to be the leader.
   B. to take an active part in discussion.
   C. to talk when I feel like it.
   D. to talk seldom.
   E. never have to talk.

10. For a science teacher I would prefer a
    A. man.
    B. woman.
    C. makes no difference.
11. Indicate which of the following activities you can do.

A. Play a musical instrument.
B. Build models (airplanes, cars, etc.).
C. Sew, thread a needle.
D. Play ball (any type of sport activity).
E. Swim.
F. None of the above.

12. In athletic activities usually I would prefer active participation in

A. team sports (football, basketball).
B. individual sports (swimming, golf, etc.).
C. to watch.
D. to take no part.

STUDENT OPINIONNAIRE -- Part 2

Indicate your feelings about the following statements by checking on the response sheet the letter which most nearly expresses your attitude.

A. Strongly agree
B. Agree
C. Neither agree or disagree
D. Disagree
E. Strongly disagree

1. I feel that I know how scientists work.
2. The teacher was interested in helping me succeed with the class work.
3. I like doing the kinds of things we did in class last year.
4. Some science background is needed by all people.
5. I feel that the teacher was interested in me as a person.
6. I feel that the basic organization of the program helped me to learn even though some parts of it needed to be revised.
7. Experiencing how scientists work is interesting.
8. People who work in scientific occupations are doing worthwhile things that benefit many people.

9. I had the freedom in class to work at a rate which was suited to my style of learning.

10. I would have done more and better work if the teacher had encouraged me more.

11. I like science.

12. What I did in school last year in science will be useful to me in later years in school.

13. The science program I had last year taught me a lot about science -- the things the world is made of and how they work together.

14. The teacher was fair and consistent in the way he worked with the students and showed no favoritism to any one group.

15. What I did in science last year will be useful to me out of school in the years ahead.
APPENDIX B

TEACHER OPINIONNAIRE

Part I

1. My age is
   A) less than 25
   B) between 26 and 35
   C) between 36 and 46
   D) more than 46

2. My sex is
   A) male
   B) female

3. My total number of college hours in science is
   A) 0-7
   B) 8-16
   C) 17-25
   D) more than 25

4. College degrees earned
   A) less than Bachelors
   B) Bachelors
   C) Masters
   D) beyond Masters

5. Total number of semester hours during the last five years is
   A) none
   B) 1-4
   C) 5-10
   D) above 10

6. Number taken in science during last five years is
   A) none
   B) 1-4
   C) 5-10
   D) above 10

7. I have taken part in the following number of science institutes
   A) 1
   B) 2
   C) 3
   D) more than three
   E) none

8. Total years of teaching experience is
   A) none
   B) 1-5
   C) 6-10
   D) above 10

9. Number of years teaching science is
   A) none
   B) 1-5
   C) 6-10
   D) more than 10

10. Total years other working experience (not summer work)
    A) none
    B) 1-5
    C) 6-10
    D) more than 10

11. Type of other work done
    A) industry or trade
    B) administrative
    C) other profession
    D) none of these

* Code numbers for use by evaluators.
OPINIONNAIRE

Part II

Instruction for items 12-41: Given below are statements on educational ideas and problems about which we all have beliefs, opinions, and proper attitudes. We all think differently about such matters, and this scale is an attempt to let you express your beliefs and opinions. Respond to each of the items as follows:

A. Agree Strongly
B. Agree
C. No Opinion
D. Disagree
E. Disagree Strongly

For example, if you agree strongly with a statement, you would indicate A on the answer sheet.

12. The goals of education should be dictated by children's interests and needs, as well as by the larger demands of society. B 3-c,1

13. No subject is more important than the personalities of the pupils. B 3-1

14. Schools of today are neglecting the three R's. B 3-e

15. The pupil-teacher relationship is the relationship between a child who needs direction, guidance, and control and a teacher who is an expert supplying direction, guidance, and control. B 3-1,e

16. Teachers, like university professors, should have academic freedom -- freedom to teach what they think is right and best. B 3-e

17. The backbone of the school curriculum is subject matter; activities are useful mainly to facilitate the learning of subject matter. B 3-c,e,r

18. Teachers should encourage pupils to study and criticize our own and other economic systems and practices. B 3-e,f

19. The traditional moral standards of our children should not just be accepted; they should be examined and tested in solving the present problems of students. B 3-1,e
20. Learning is experimental; the child should be taught to test alternatives before accepting any of them.

21. The curriculum consists of subject matter to be learned and skills to be acquired.

22. The true view of education is so arranging learning that the child gradually builds up a store house of knowledge that he can use in the future.

23. One of the big difficulties with modern schools is that discipline often is sacrificed to the interests of the children.

24. The curriculum should contain an orderly arrangement of subjects that represent the best of our cultural heritage.

25. Discipline should be governed by long-range interests and well-established standards.

26. Education and educational institutions must be sources of new social ideas; education must be a social program undergoing continual reconstruction.

27. Right from the very first grade, teachers must teach the child at his own level and not at the level of the grade he is in.

28. Children should be allowed more freedom than they usually get in the execution of learning activities.

29. Children need and should have more supervision and discipline than they usually get.

30. Learning is essentially a process of increasing one's store of information about the various fields of knowledge.

31. In a democracy, teachers should help students understand not only the meaning of democracy but also the meaning of the ideologies of other political systems.
Part III

Instructions: On the answer sheet, place the letter which represents the response which indicates, most nearly your opinion.

32. I would consider myself to be a
   A. strict disciplinarian.
   B. moderately strict disciplinarian.
   C. average disciplinarian.
   D. moderately lenient disciplinarian.
   E. lenient disciplinarian.

33. I would prefer to be teaching
   A. Science.
   B. Social Studies.
   C. English.
   D. a non-required course.
   E. anything but science.

34. As a teacher
   A. I am always ready to try new techniques.
   B. I have developed a satisfactory teaching style which needs little change.
   C. I am cautious about new teaching techniques.
   D. I have never found an innovation to be very satisfactory.
   E. I have found that new techniques are always the best.

35. Teachers should be
   A. friendly toward students.
   B. polite but not overly friendly.
   C. aloof and firmly in command.
   D. totally detached, very impersonal.

36. As a teacher, I would
   A. work hard to implement team teaching in the classroom.
   B. enjoy working with a team teacher.
   C. be very selective if team teaching.
   D. team teach only if asked by my superior.
   E. rather not team teach.
37. As a teacher, I feel department Planning Meetings are
   A. absolutely essential.
   B. of a great benefit.
   C. sometimes helpful.
   D. usually non-productive.
   E. a waste of time.

38. Aside from teaching, my favorite activity is
   A. reading.
   B. household duties.
   C. sports - active.
   D. sports - spectator.
   E. hobbies - (collecting stamps, rocks, etc.).

39. In a small group discussion with my students I would prefer to
   A. have the teacher define a task and the roles of the students in the accomplishment of the task. (see drawing at right)**
   B. take an active part, present many facts to the group. (see drawing at right)
   C. allow the students to guide the discussion themselves. (see drawing at right)
   D. talk seldom but give guidance when needed. (see drawing at right)
   E. be a consultant, emphasizing individual instruction. (see drawing at right)

40. The administrators in our school
A. are receptive to constructive ideas for change.
B. are glad to give recognition to persons who make
   good suggestions.
C. take suggestions under consideration sometimes.
D. prefer well-established procedures.
E. are cautious about adapting new measures.

41. I feel the best grading terms are
A. satisfactory - unsatisfactory.
B. a check list of student behaviors.
C. letter grades.
D. percentage grades.
E. no grades.
APPENDIX C

SCHOOL ADMINISTRATOR OPINIONNAIRE

Part I

Do not write your name or the name of your school system on the answer sheet. Instead, please use an identifying number, the last four digits of your social security number, or make up a number that you wish to use, and write it in the space provided for names. No other data is needed in the heading. Mark the letter on the answer sheet that is appropriate for the following statements.

1. My age is  
   A) less than 25  
   B) between 26 and 35  
   C) between 36 and 46  
   D) more than 46

2. My sex is  
   A) male  
   B) female

3. My total number of college hours in science is  
   A) 0-7  
   B) 8-16  
   C) 17-25  
   D) more than 25

4. College degrees earned  
   A) Bachelors  
   B) Masters  
   C) beyond Masters  
   D) Doctors

5. Total number of semester hours during the last five years is  
   A) none  
   B) 1-5  
   C) 6-10  
   D) more than 10

6. Number taken in science during the last five years  
   A) none  
   B) 1-5  
   C) 6-10  
   D) more than 10

7. Total number of years as a school administrator  
   A) none  
   B) 1-5  
   C) 6-10  
   D) more than 10

8. Total years of teaching experience  
   A) none  
   B) 1-5  
   C) 6-10  
   D) more than 10

9. Number of years teaching science  
   A) none  
   B) 1-5  
   C) 6-10  
   D) more than 10

* Code numbers for use by evaluators
10. Total years other working experience (not summer work)  
   A) none  B) 1-5  C) 6-10  D) more than 10

11. Type of other work done  
   A) industry or trade  C) other profession  
   B) administrative  D) none of these

ADMINISTRATOR OPINIONNAIRE

Part II

Instruction for items 12-41: Given below are statements on educational ideas and problems about which we all have beliefs, opinions, and proper attitudes. We all think differently about such matters, and this scale is an attempt to let you express your beliefs and opinions. Respond to each of the items as follows:

A) Agree Strongly  D) Disagree  
B) Agree  E) Disagree Strongly  
C) No Opinion

For example, if you agree strongly with a statement, you would indicate A on the answer sheet.

12. The goals of education should be dictated by children's interests and needs, as well as by the larger demands of society.

13. No subject is more important than the personalities of the pupils.

14. Schools of today are neglecting the three R's.

15. The pupil-teacher relationship is the relationship between a child who needs direction, guidance and control and a teacher who is an expert supplying direction, guidance, and control.

16. Teachers, like university professors, should have academic freedom -- freedom to teach what they think is right and best.

17. The backbone of the school curriculum is subject matter; activities are useful mainly to facilitate the learning of subject matter.
18. Teachers should encourage pupils to study and criticize our own and other economic systems and practices.  

19. The traditional moral standards of our children should not just be accepted; they should be examined and tested in solving the present problems of students.  

20. Learning is experimental; the child should be taught to test alternatives before accepting any of them.  

21. The curriculum consists of subject matter to be learned and skills to be acquired.  

22. The true view of education is so arranging learning that the child gradually builds up a store house of knowledge that he can use in the future.  

23. One of the big difficulties with modern schools is that discipline is often sacrificed to the interests of the children.  

24. The curriculum should contain an orderly arrangement of subjects.  

25. Discipline should be governed by long-range interests and well-established standards.  

26. Education and educational institutions must be sources of new social ideas; education must be a social program undergoing continual reconstruction.  

27. Right from the very first grade, teachers must teach the child at his own level and not at the level of the grade he is in.  

28. Children should be allowed more freedom than they usually get in the execution of learning activities.  

29. Children need and should have more supervision and discipline than they usually get.  

30. Learning is essentially a process of increasing one's store of information about the various fields of knowledge.
31. In a democracy, teachers should help students understand not only the meaning of democracy but also the meaning of the ideologies of other political systems.

Part III

Instructions: On the answer sheet, mark the letter which represents the response expressing most nearly your opinion.

32. I would consider myself to be a
A. strict disciplinarian.
B. moderately strict disciplinarian.
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D. moderately lenient disciplinarian.
E. lenient disciplinarian.

33. When teaching, the subject I would prefer is
A. Science.
B. Social Studies.
C. English.
D. a non-required course.
E. anything but science.

34. As an administrator
A. I am always ready to try new techniques.
B. I feel the "tried and true" traditional style of teaching needs little changes.
C. I am cautious about new teaching techniques.
D. I have never found an innovation to be very satisfactory.
E. I have found that new techniques are always the best.

35. Teachers and administrators should be
A. friendly toward students.
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36. As a teacher, I would
A. work hard to implement team teaching in the classroom.
B. enjoy working with a team teacher.
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      group. (see drawing at right)
   C. allow the students to guide the discussion
      themselves. (see drawing at right)
   D. talk seldom but give guidance when needed.
      (see drawing at right)
   E. be a consultant, emphasizing individual instruction.
      (see drawing at right)

** Glatthorn, Allen A., "Learning in Small Groups", Abington
      High School, North Campus, Abington, Pa., 1967.
40. The administrators in our school
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   A. satisfactory - unsatisfactory.
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