THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE INFLUENCE OF THE SCIENCE CURRICULUM IMPROVEMENT STUDY ON THE LEARNER'S OPERATIONAL UTILIZATION OF SCIENCE PROCESSES

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF EDUCATION

BY

MARVIN C. WEBER

Norman, Oklahoma

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OF SCIENCE PROCESSES

APPROVED BY

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CHAPTER I

INTRODUCTION

Background of the Study

Science education in the United States took a new pedagogical direction shortly before the appearance of Sputnik in 1957. The Physical Science Study Committee was established at the Massachusetts Institute of Technology to redesign secondary school physics. Curriculum reform was underway in science.

This study is directed toward the assessment of a science program which resulted from that reform movement. This program, developed by the Science Curriculum Improvement Study, is designed for the elementary school.

A major impetus for that science curricular reform was provided by the National Science Foundation when a new philosophy emerged for granting financial support to curriculum development projects. The thesis of this new philosophy can be summarized as follows:

> In very many ways the plans and expectations of Americans, and indeed of people everywhere, depend upon a strong and growing science and technology. The increasing importance of science to our nation and the world creates pressing educational demands. Literacy in science is becoming essential for all citizens who wish to comprehend the world they live in and work in and to participate in the increasing number of local and national decisions, some of gravest import, that require an understanding of science. Further, more and more students must be attracted to scientific and technical pursuits . . . In the last few years, scientists, mathematicians, engineers, and educators have taken up these new educational challenges with great vigor. Working together, and aided by increasing public and private support for educational research and development, they have undertaken a number of fresh approaches to the improvement of school instruction in science and mathematics. In colleges and universities, research scientists have been taking an increasing interest in undergraduate instruction. The aim has been to see that instruction presents contemporary knowledge as well as contemporary viewpoints on knowledge established earlier. In many cases it has seemed best to start anew rather than merely to patch up older courses. A distinctive feature of many projects is the effort made to go beyond the presentation of what is known and to provide students with experience in the processes by which new facts, principles, and techniques are developed.[1]

The processes mentioned in the above paragraph obviously refer to the very operations in which the scientist is engaged or, more adamantly stated, those processes are the processes of science. The incorporation of those processes, then, into the learning activities was a major aim of the newly formed curriculum projects.

Several groups and organizations have identified processes which characterize the scientific enterprise and,

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[1]Course and Curriculum Improvement Projects, with a forward by Thomas D. Fontaine, Vol. NSF 66-22 (Washington, D.C.: Government Printing Office, 1966), p. iii.

also, the kind of intellectual activity which each process requires. The American Association for the Advancement of Science (AAAS), for example, has identified thirteen processes which are considered to be representative of scientific activity. Those processes for the lower grades are observing, classifying, using space/time relationships, using numbers, measuring, communicating, predicting, and inferring. Here then is a definition of science processes which are appropriate for primary children to experience. Included in the upper grade AAAS program are the processes of formulating hypotheses, controlling variables, interpreting data, defining operationally, and experimenting.[2] Renner and Ragan[3] have listed five processes which they consider essential to the work of the scientist. Those processes are: observing, classifying, experimenting, interpreting, and predicting. Obviously there is similarity between these two lists of science processes.

The re-directed pedagogy of the curriculum reform movement placed science education in a new light. No longer were all science educators content with the traditional view of science which emphasized its factual nature. Nor were they content with accepting science as a static body of

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[2]Science--A Process Approach (New York: Xerox Corporation, 1967), pp. 2-3.

[3]John W. Renner and William B. Ragan, Teaching Science in The Elementary School (New York: Harper and Row, 1968), pp. 112-197.

knowledge to be gleaned from a book, a lecture, or a demonstration. Those concerned with science education were no longer content to allow the learner in science to remain as a passive individual toward which a body of knowledge would be directed.

Those behind the national science curriculum reform movement were dedicated to the development of a completely different approach to classroom science teaching and learning. They wanted science to be taught and learned in the same manner through which the scientist approached his work; they also wanted the learner to become actively involved while acquiring the conceptual schemes necessary to scientific literacy. In the emerging science curricula, the learner is engaged in the processes which lead to concept development.

Since that first new physics course was introduced in 1957, the National Science Foundation has supported many other projects aimed at the development of new curriculum materials for the elementary, junior high, and the secondary school science courses. In September, 1966, the Foundation was supporting sixty-six such projects.[4]

Each of the new projects was incorporating to some degree, the philosophy which was being promoted in the reform movement. A special descriptive term, inquiry, began appearing in the literature when references were made to the new

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[4] Course and Curriculum Improvement Projects, pp. 3-32.

science curricula and that term was also used to describe the new approaches in science education. Thus, the term, inquiry, was being used to denote the philosophical differences between the new science curricula and the older, more conventional, textbook-oriented approaches in science.

By 1971, many of the projects had been terminated, either because their work was completed or because of other circumstances. The inquiry approach, however, continues to be stressed in those programs which are still active and in other independently developed science programs. Perhaps more importantly, the inquiry philosophy is beginning to permeate the thinking of educators in many disciplines other than science. The Science Curriculum Improvement Study (SCIS) is such a science program which focuses on the elementary school level.

The Science Curriculum Improvement Study originated in Berkeley, California, in 1959, supported by a grant from the National Science Foundation.[5] Dr. Robert Karplus, the project's director, has been assisted by numerous educators, scientists, and psychologists in developing the curriculum. As the curriculum was developed, it was experimentally used in several trial center schools located in East Lansing, Michigan; Honolulu, Hawaii; Los Angeles, California; Norman, Oklahoma; and New York, New York. Those experimental trials

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[5] Ibid., p. 5.

were primarily for seeking feedback information as opposed to functioning for the purpose of evaluation because the initial thinking was that the project would not make comparative evaluations until the curriculum was complete.[6] The philosophy of this curriculum approach can be succinctly related by quoting Karplus and Thier from an early publication.

> The Science Curriculum Improvement Study is attempting to develop a teaching program to increase the scientific literacy in the school and adult populations. To accomplish this aim, the study has to formulate a view of the nature and structure of science; it has to devise learning experiences that achieve a secure connection between the pupils' intuitive attitudes and the concepts of the modern scientific point of view . . . The function of education is to guide the children's development by providing them with particularly informative and suggestive experiences as a base for their abstractions. At the same time, children must be led to form a conceptual framework that permits them to perceive phenomena in a more meaningful way and to integrate their inferences into generalizations of greater value than they would form if left to their own devices.[7]

A later SCIS publication states that a person's scientific literacy results from his basic knowledge, investigative experience, and curiosity. In the SCIS program these three factors are integrated, balanced, and developed through the children's involvement with major scientific concepts, key process-oriented concepts, and challenging problems for

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[6]Willard Jacobson and Allan Kondo, SCIS Elementary Science Sourcebook (Berkeley, Calif.: Science Curriculum Improvement Study, 1968), p. iii.

[7]Robert Karplus and Herbert Thier, Toward Scientific Literacy (Boston: D. C. Heath and Company, 1966), p. 1.

investigation. The children are introduced to knowledge of scientific content through their experiences with diverse physical and biological materials. And in the course of their investigations, they are engaged in observation, measurement, interpretation, prediction, and other processes.[8] It is apparent from the available philosophical statements that the goals of SCIS are pursued through activities which involve the learner in the operational processes just identified. The SCIS program, then, has a conceptual framework which is bound together by science processes.

Logically, then, an assessment of the effectiveness of the SCIS curriculum could be approached through its influence on the development of the learner's operational utilization of selected science processes. This was the premise on which this study was based.

Statement of the Problem

The problem to which this study was directed was to assess the effectiveness of the Science Curriculum Improvement Study curriculum in developing the learner's ability to utilize selected science processes. The processes which were selected for this assessment were observation, classification, measurement, interpretation, experimentation, and prediction.

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[8] SCIS Sample Guide (Chicago: Rand McNally and Company, 1970), p. 6.

Need for the Study

The SCIS curriculum has been widely adopted in schools across the United States even though there are no available date with respect to its effectiveness as a science curriculum. Oklahoma is not an exception. The SCIS curriculum is also used in Oklahoma schools, an approach which is recommended in the state science curriculum guide.[9] These Oklahoma implementations can perhaps be attributed to the influential activity of the SCIS trial center located at the University of Oklahoma in Norman.[10]

Another factor which pointed to the need for this study was the four million dollars in public money which the project had received since its inception.[11] Again, this large amount of money was granted even though there were no available data which would indicate the effectiveness of the curriculum. This large amount of public money which has been invested in program development and the increasing number of schools which are implementing the curriculum present an urgency for obtaining research data which will permit the SCIS program to be evaluated as a science curriculum. No

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[9]State Science Curriculum Committee, The Improvement of Science Instruction in Oklahoma: Grades K-6 (Oklahoma City: State Department of Education, 1968), p. 12.

[10]Jacobson and Kondo, SCIS Elementary Science Sourcebook, p. 3.

[11]George Moynihan, Business Manager for the Science Curriculum Improvement Study, a personal letter of May, 1970.

wide-scale attempt has been made to do this during the ten years of program development.

Hypotheses of the Study

One major null hypothesis was formulated to be tested against a major alternative for the purpose of providing direction in the development of this study. Additionally, six subsidiary null hypotheses with the alternatives were also designed. These hypotheses are as follows:

Major Null Hypothesis and The Major Alternative

H_o = No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to utilize science processes.

H_1 = The student in the SCIS program will develop a significantly greater ability to utilize science processes than will the student in textbook science.

Subsidiary Null Hypotheses and The Subsidiary Alternatives

H_o = No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to observe.

H_2 = The student in the SCIS science program will develop a significantly greater ability to observe than will the student in textbook science.

H_o = No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to classify.

H_3 = The student in the SCIS science program will develop a significantly greater ability to classify than will the student in textbook science.

H_o = No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to measure.

H_4 = The student in the SCIS science program will develop a significantly greater ability to measure than will the student in textbook science.

H_o = No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to experiment.

H_5 = The student in the SCIS science program will develop a significantly greater ability to experiment than will the student in textbook science.

H_o = No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to interpret.

H_6 = The student in the SCIS science program will develop a significantly greater ability to interpret than will the student in textbook science.

H_o = No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to predict.

H_7 = The student in the SCIS science program will develop a significantly greater ability to predict than will the student in textbook science.

Limitations of the Study

Research studies usually have certain limitations. This investigation was no exception. It too had inherent limits. The reader is encouraged to carefully consider those limitations when interpreting the results obtained in this study. The limitations are delineated below.

(1) The research procedures of this study were such that the investigation is representative of ex post facto research. Kerlinger defines ex post facto research as follows:

> Research in which the independent variable or variables have already occurred and in which the researcher starts with the observation of a dependent variable or variables. He then studies the independent variables in retrospect for their possible relations to, and effects on, the dependent variable or variables.[12]

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[12]Fred N. Kerlinger, Foundations of Behavior Research (New York: Holt, Rinehart, and Winston, 1964), p. 360.

Thus, the independent variable in this study, learning science through the SCIS curriculum, occurred during the four and one-half years prior to assessment. This is in keeping with the above definition; the independent variable had already occurred before the study was designed.

Ex post facto research has three major weaknesses which are (1) the inability to manipulate independent variables, (2) the lack of power to randomize, and (3) the risk of improper interpretation.[13] These first two weaknesses are identifiable in this investigation and the third was previously identified for the reader.

Kerlinger further states that despite its weaknesses, much ex post facto research must be done in psychology, sociology and education simply because many research problems in the social sciences and education do not lend themselves to experimental inquiry.[14] The reader is cautioned at this point not to view ex post facto research as being undesirable in research work. Indeed, many studies would not be possible were it not for the ex post facto approach. In fact, ex post facto research is probably more important than experimental research because sometimes its designs are the only ones possible.[15] So it is with this investigation. The study

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[13] Ibid., p. 371.

[14] Ibid., p. 372.

[15] Ibid., p. 373.

would not have been possible in the true spirit of experimental research.

(2) This investigation was based on the assessment of the learner achievement of the six science processes of observation, classification, measurement, experimentation, interpretation, and prediction. Those processes were selected by the investigator as being representative of scientific process and the processes utilized in the SCIS program. Because no measuring instrument was available, the investigator had to construct one. The results of the research must be viewed in terms of the instrument's reliability, validity, and discriminatory power.

(3) This study also contained the limitation of subject selection. The population of the experimental group was limited because of the small number of schools using the SCIS science curriculum. In this study forty-six students were identified as having studied SCIS science for four and one-half years. This population represented the total number of students who had studied SCIS science for the most consecutive years in the state of Oklahoma. Those students were from the middle and upper strata of the socio-economic levels in their respective communities. Indicative of this limitation also was the fact that the group's mean intelligence level was above the considered average.

Review of the Literature

The number of research studies relating to the Science Curriculum Improvement Study is quite limited, especially those concerned with SCIS evaluation. Several studies related to the teaching strategies of SCIS-oriented educators were, however, available in the literature.

Siegelman and Karplus[16] evaluated the trial edition of Relativity, a SCIS unit designed for third grade students. The evaluation was made relative to the student's performances on tasks designed to measure the attainment of five objectives of the unit. Those five objectives were:

1. To describe and identify the position of objects relative to reference objects in the children's immediate environment.

2. To describe the position of objects relative to Mr. O.[17]

3. To understand and use one, two, or three major directions in a description of relative position.

4. To observe and identify motion relative to Mr. O.

5. To observe and identify motion relative to objects or systems other than Mr. O.

All tests consisted of a pictorial group test on the relative position concept and an individual interview on the

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[16] Robert Karplus, ed., What Is Curriculum Evaluation--Six Answers (Berkeley: Science Curriculum Improvement Study, 1968), pp. 3-8.

[17] Mr. O. is a paper, stick-man used in the Relativity unit. It is an artificial observer used to lead the child to think of the relative placement of objects from viewing positions other than the child's.

relative motions concept. Twenty-eight children were given the test before and after they were taught the _Relativity_ unit. Results indicated the unit definitely aided the children in developing strong spatial relationships. Also, objectives two and three were successfully attained while only partial attainment of objectives one, four, and five was accomplished.

Hagen[18] evaluated the degree to which the SCIS first grade unit, _Material Objects_, allowed the students to attain several behavioral objectives. She and her colleagues administered student performance tests to first graders in California, Oklahoma, and New York. They determined the unit significantly led to the students' development of those objectives.

Stafford and Renner[19] studied the influence of inquiry-centered teaching on the intellectual development of children. Their study also focused on the _Material Objects_ unit as the content vehicle of the study. They found the unit to significantly accelerate the development of conservation reasoning in children. According to Piaget[20] conservation reasoning is

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[18] Elizabeth Hagen, "Developmental Evaluation of _Material Objects Unit_," (unpublished evaluation study of the Science Curriculum Improvement Study, 1966).

[19] Don G. Stafford and John W. Renner, "SCIS Helps the First Grader to Use Logic in Problem Solving," _School Science and Mathematics_, February, 1971, pp. 159-164.

[20] Jean Piaget, _Psychology of Intelligence_ (Patterson, N.J.: Littlefield, Adams, and Company, 1963), p. 123.

one of the developmental stages in intellectual growth through which every individual progresses. Thus, the SCIS curriculum definitely leads to accelerated intellectual development in children.

Allen[21] determined there was no significant difference in the development of classification skills by students who had had SCIS science for two years and those who hadn't. His study was based on the performance of middle class students in grades two, three and four.

Kellogg[22] determined the SCIS unit, <u>Material Objects</u>, served as a valid reading readiness experience for students entering the first year of school. In his study he compared a group of first graders who studied SCIS science as their only reading readiness program with a second group who participated in a leading, conventional reading readiness program. On a test, retest comparison, the SCIS group made significantly greater gains in readiness.

Coffia[23] determined that students in the SCIS program attained a higher level of achievement in mathematics, social

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[21] Leslie Robert Allen, "An Examination of the Classificatory Ability of Children Who Have Been Exposed to One of the "New" Elementary Science Programs" (unpublished doctoral dissertation, University of California, 1967).

[22] Don Kellogg, "An Investigation of the Effect of the Science Curriculum Improvement Study's First Year Unit, <u>Material Objects</u>, on Gains in Reading Readiness" (unpublished doctoral dissertation, University of Oklahoma, 1971).

[23] William Coffia, "The Effects of an Inquiry-Oriented Curriculum in Science on a Child's Achievement in Selected Academic Areas" (unpublished doctoral dissertation, University of Oklahoma, 1971).

studies, and reading when compared to students in a textbook-centered science program. The students in both the SCIS and the textbook programs had been learning in their respective curricula for almost five years when the comparisons were made.

Several studies were available which indicated teachers, who had been educated in the basic SCIS philosophy, significantly required their students to operate at higher intellectual levels. This was determined through the kinds of classroom experiences those teachers provided and the kinds of questions which were asked in the classroom.

Wilson and Renner[24] compiled observational data from thirty classrooms in the first through the sixth grades. Fifteen science classes were taught by teachers who had had educational orientation to the SCIS philosophy and were using the curriculum in their science classes. The other fifteen teachers had had no prior SCIS orientation and were using the conventional textbook approach in their science classes. In comparing the two groups as to the kinds of science experiences and the kinds of questions which were asked, they found the following:

1. The SCIS educated teachers provided more of the essential experiences[25] of science in their classes than did the conventional group.

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[24] John H. Wilson and John W. Renner, "The New Science and the Rational Powers: A Research Study," Journal of Research in Science Teaching, VI (1969), pp. 303-307.

[25] Renner and Ragan, Teaching Science, pp. 112-197.

2. Recognition and recall types of questions were asked to a greater extent by the conventional group.

3. Analysis and synthesis types of questions were asked to a greater extent by the SCIS group.

4. Comprehension types of questions were asked in greater numbers by the conventional group whereas demonstration of skill questions were asked in greater numbers by the SCIS teacher-oriented group.

Schmidt[26] made observations of sixteen teachers before and after they participated in a workshop which provided experiences in the SCIS program. A comparison was made of the kinds of social studies and science experiences which they provided in the classroom and the kinds of questions asked before and after the teachers attended the workshop. He found the workshop experience caused a change in certain teacher behaviors. The SCIS-educated teachers asked fewer recall and convergent questions, asked more questions which required the pupils to operate at higher rational levels, and provided the pupils with a greater number of essential learning experiences in science.[27] Of special significance was Schmidt's finding that those teacher behavior changes influenced the way the teachers involved taught their social studies classes after the workshop experience even though traditional social studies materials were used.

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[26]John W. Renner and Donald G. Stafford, "Inquiry, Children and Teachers," The Science Teacher, XXXVII, No. 4 (April, 1970), pp. 55-57.

[27]Renner and Ragan, Teaching Science, pp. 112-197.

Porterfield[28] studied how the SCIS curriculum and philosophical orientation influenced the questioning strategy of elementary teachers in the teaching of reading. He found teachers who had had experience with the SCIS philosophy definitely altered their questioning techniques. His conclusions are summarized as follows:

1. Teachers not having had SCIS exposure asked questions which were based on recognition and recall abilities.

2. The SCIS oriented teachers asked more questions of the translation, analytical, and synthesis types.

3. The SCIS teachers asked fewer recall questions.

Based upon the data from the research just reviewed, it is evident that the SCIS program influences learner achievement in areas other than science and teaching that program affects the manner in which teachers view their responsibilities. The investigator believed the next question that needed to be asked was the one to which this study was directed.

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[28] Renner and Stafford, "Inquiry, Children, and Teachers," pp. 55-57.

CHAPTER II

PROCEDURES OF THE STUDY

Overview

This study assessed the effectiveness of the SCIS curriculum in developing the learner's ability to operationally utilize science processes. The assessment was made by comparing the scores obtained on a science process instrument by two groups of students; one group had studied science by using the SCIS curriculum while the second group of students had studied science through the textbook approach.

The procedures of this study involved four major steps: (1) the construction of the instrument, (2) the selection of the subjects, (3) administering the instrument, and (4) analyzing the data.

The Process Instrument

All attempts to evaluate the operational level of learner utilization of science processes have been hindered by the absence of measuring instruments. The same was true for this study. No instrument was available; consequently, one had to be constructed.

The instrument was designed to assess student performance on tasks which represented the six processes which were identified in Chapter I. Those processes were observing, classifying, measuring, experimenting, interpreting, and predicting. Student performance tasks were constructed to assess each science process. The performance of these tasks were rated either as acceptable or unacceptable; an acceptable response was assigned the numeral 1 and an unacceptable response was assigned the numeral 0. The assignment of these numerals permitted the quantification of the responses in attaining a quantitative level of measurement for a statistical analysis. Because the instrument consisted of thirty-four scoring possibilities, the highest score possible was thirty-four. A copy of this instrument with the student scoring sheet will be found in Appendix A.

Instrument Reliability

The reliability of this process instrument was ascertained by administering the instrument to a randomly selected group of twenty, fifth grade students from East Elementary School in Weatherford, Oklahoma. Those students had had two years of SCIS science in grades three and four. None of those students used to establish the instrument's reliability participated in the portion of the study in which the SCIS curriculum was assessed. The reliability coefficient for internal consistency was determined by the Rulon split-half method as presented by Magnusson.[29]

The data and the mathematical treatment of the Weatherford responses will be found in Appendix B. The data from this sample yielded a reliability coefficient of 0.64. In response to the question of what level reliability one should attain, Guilford offers the following explanation.

> As to how high reliability coefficients should be, no hard and fast rules can be stated. For research purposes, one can tolerate much lower reliabilities than one can for practical purposes of diagnosis and prediction. We are frequently faced with the choice of making the best of what reliability we can get, even though it may be of the order of only 0.50, or of going without the use of the test at all.[30]

Instrument Validity

The instrument's validity was established by asking a panel of science educators to rate each (process) task on the instrument according to the level (excellent, highly representative, suitable, and not representative) to which that task measured the utilization by the learner of the science process for which it was designed. The rating levels were assigned the following numerical values: 1 for the excellent rating; 2 for the highly representative rating; 3 for the suitable rating; and 4 for the not representative rating.

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[29]David Magnusson, Test Theory (Reading, Mass.: Addison-Wesley Publishing Company, 1966), p. 111.

[30]J. P. Guilford, Psychometric Methods (New York: McGraw-Hill Book Company, 1954), p. 388-89.

Those ratings were then statistically analyzed in accordance with Walker and Lev.[31] The data were treated to determine the significance of the choices, i.e., in order to find whether the rating choices were due to chance alone.

The following educators were selected for the panel. A brief statement regarding the educator's professional responsibilities follows each name.

Dr. Glen Berkheimer . . . . . . Michigan State University	Director of the SCIS Trial Center in East Lansing, Michigan
Dr. David Butts . . . . University of Texas	An active implementor in the curriculum project, <u>Science--A Process Approach</u>.[32] This curriculum approach is entirely process oriented.
Mr. Stanford Davis . . . . . . U.C.L.A.	Mr. Davis is the Director of the SCIS Trial Center in Los Angeles, California.
Mr. Jack Fishleder	Mr. Fishleder is the SCIS project coordinator headquartered in Berkeley. He has been closely involved in the internal design and national implementation of the curriculum.

Because of the professional experience of those educators, this investigator believes they were qualified to rate the

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[31] H. M. Walker and Joseph Lev, *Statistical Inference* (New York: Holt, Rinehart, and Winston, 1963), p. 37.

[32] John Mayor and Arthur Livermore, Project Directors, American Association for the Advancement of Science, Washington, D.C.

appropriateness of the tasks on the instrument. Those ratings and accompanying statistical treatment will be found in Appendix C.

The results of the statistical treatment yielded levels of significance which ranged from a minimum 0.0082 to a maximum 0.000013. The levels indicated the probabilities of the panel's ratings varied from eighty-two chances in ten thousand to thirteen chances in one million in being due to chance alone. Because the size of these odds was so large against chance occurrence, the panel's ratings were accepted as being representative of a high level of validity. Consequently, the instrument was accepted as being valid.

Instrument Discriminatory Power

A critical question in the construction of the process instrument was whether it would discriminate between the performances of the SCIS and the non-SCIS student on the process tasks. Magnusson[33] states one method for determining discriminatory power is to determine the frequency of correct response for the items. This frequency is usually expressed as a p-score, which gives the proportion of the total number of individuals who successfully responded to the item. The p-score, then, is the quotient obtained by dividing the number of correct responses by the number of possible responses.

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[33]Magnusson, Test Theory, p. 219.

Magnusson[34] further states that maximum discrimination exists when the p-score is equal to 0.50.

The responses obtained in the preliminary study, i.e., with the Weatherford group, were treated by this method in determining the discriminatory power of the instrument. This treatment yielded the following levels of discrimination: observing, 0.34; classifying, 0.64; measuring, 0.35; experimenting, 0.25; interpreting, 0.38; and prediction, 0.67. The p-score for the total instrument was 0.43. The responses of the Weatherford group and the p-score computations are found in Appendix D.

Selection of Subjects

The design of this investigation provided that two groups of students were to be selected; one group was to have studied science through the SCIS curriculum while the second group was to have studied science by using a textbook-centered curriculum. An obvious benefit to the problem being investigated would be to select students who had been in a particular science program for a long enough period of time to allow that program to make a definite impact on them. The students in the SCIS group (designated as the experimental group) were 46 fifth graders from a Norman, Oklahoma, school. They had studied science through the SCIS curriculum in that school since the first grade. Those students were significant to

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[34] *Ibid.*

this investigation because they had been studying the SCIS science program longer than any other students in the state of Oklahoma.

The second group (the control group) consisted of students who had been in a conventional science textbook-centered curriculum. The Norman schools could not be used as a source for this group because nearly all the students and teachers had been exposed to the SCIS curriculum approach. The students in this group were selected from a school in Putnam City, Oklahoma. They also were fifth graders and had attended this particular school since the first grade.

The Putnam City school was selected to provide the students for the control in this study because of the school's similarity to the Norman school. Its students were comparable to the Norman students with regard to the factors of intellectual and socio-economic levels. Additionally, the parents of both groups were engaged in comparable occupations. A search of the records in this control school identified 69 students who had been in the textbook approach since they had entered their first year of school.

The validity of this study was directly dependent on how closely the two groups and the individuals were matched on all factors except for the science instruction. Factors in group comparability were learning readiness, school organization, curricular organization, and teacher variability.

Individual comparability was achieved by matching the subjects on the factors of chronological age, I.Q., sex, and socio-economic levels. These data are found in Appendix E.

Comparability of the Experimental and Control Groups

Readiness for Learning

The students in both the experimental and control groups were comparable in their readiness to learn upon entering their first year of school in the fall of 1966. Coffia[35] established the readiness of the 46 SCIS students and the 69 science textbook students in a previous study. Both groups had scores recorded from the Metropolitan Reading Tests[36] upon entering the first grade. This test consists of six individual tests: Word Meaning, Listening, Matching, Alphabet, Numbers, and Copying. The scores from these individual tests are combined to provide a total readiness score. This total readiness score was then used for comparing the two groups. The chi-square statistical test was used to test the hypothesis that no significant difference existed between the two groups in learning readiness when first entering school. The computed chi-square was significant for p 0.20. Consequently, the hypothesis was accepted and the two groups were

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[35]William Coffia, "The Effects of an Inquiry-Oriented Curriculum."

[36]Walter N. Durost, ed., Metropolitan Reading Tests (New York: Harcourt, Brace, and World, 1959).

considered comparable in readiness for learning when the students entered the first grade.

School Organization[37]

The organizational structure of the two schools was similar in that they followed the self-contained classroom concept until grade five where they were then departmentalized. In the first four grades of the self-contained classroom structure, specialized teachers were used in certain fields as in music or art. The experimental group did experience one exception to the above structure in the fourth grade where the instructional approach of team teaching was introduced. The investigator believes neither group received any particular advantage toward the development of science processes as the result of its school's organizational plan.

Curricular Organization[38]

The curriculum, with the exception of the science program, was observed to be quite similar in the two schools. Of vital concern in comparing the two curricula, the degree to which science process utilization might have been developed in other academic disciplines had to be ascertained.

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[37] Much of this information was acquired through conversations and interviews with the following individuals: Mr. Leonard Bates and Mr. Jerry Maynard of the Putnam City School System and Mr. Bill Sullivan and Mrs. Jack Herron of the Norman School System during the spring, 1971.

[38] Ibid.

Descriptions of the curricular areas of mathematics, social studies, and language arts in the two schools are presented below.

Mathematics. The mathematics curriculum differed somewhat in grades one and two for the two schools. The control group was involved in a more traditional program which emphasized drill and mastery of facts along with a brief treatment of some modern concepts. The experimental group did use a more modern program in grades one and two but a different program than was used later in grades three, four, and five.

Different commercial programs were implemented in both schools at the beginning of the third grade for each group. While the commercial materials weren't the same, both were considered to be comparable in presenting the philosophies and concepts of modern mathematics.[39] Neither curriculum seemed to present any overt advantage over the other toward developing the student's ability to utilize science processes.

Social Studies. The two schools follow Plan One as recommended by the Oklahoma Curriculum Improvement Commission on elementary school curricula for the social studies.[40] In

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[39] Phillip Gibbons, 1970-71, President of the Oklahoma Council of Teachers of Mathematics Association. A personal conversation on May 14, 1971.

[40] The Oklahoma Curriculum Improvement Commission, *The Improvement of Instruction in Geography, History, Political Science, Economics, and Related Areas Grades K-12* (Oklahoma State Department of Education, Oklahoma City, Oklahoma, 1966), p. 9.

this plan, the study of the home is begun in grade one with the scope expanded to include the local school, the local community, other communities, the local state, the United States, and consummating with the study of other countries in grade six. There was no observable advantage in either social studies program for developing science processes.

Language Arts. The two schools follow a similar plan for the teaching of language arts. In grade one, the program is informal with no commercial textual materials used with the exception of the reading program. Both schools initiate a textual program at the second grade level. While the experimental school did not seem as formal in structure at the second grade level as the control school, there did not appear to be a particular advantage in either program for developing the processes of science as identified in this study.

Teacher Variability[41]

The teaching philosophy of the teachers who taught the students in the two groups had to be identified in this study. In the assessment of the SCIS curriculum, with the textbook-centered curriculum serving as the control, one is essentially comparing an inquiry approach to a non-inquiry approach. Logically, then, the degree to which inquiry teaching methods were used with the two groups had to be ascertained.

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[41]Bates, et al. Conversations and interviews with the personnel in the experimental and the control schools. See footnote number 37.

Ideally, one would like to say that no inquiry was used with the textbook group, while all inquiry was used with the SCIS group. Realistically, however, one has to speak in terms of the degree to which inquiry methods were used by the teachers of the two groups.

Every teacher of the SCIS group had had formal and planned experience with the SCIS curricular materials prior to teaching the program. Those experiences included basic confrontations with the methods of inquiry in science teaching and learning.

Conversely, the control school had not introduced any inquiry-oriented programs in science or other discipline areas. Nor had there been any formal attempts to introduce the philosophy of the inquiry approach to the teachers of this school. Stating, however, that absolutely no inquiry methods were ever used in this school is rather absurd. All teachers probably use some degree of inquiry at some time.

It was readily apparent that the experimental school had used the methods and philosophy of inquiry to a much greater degree in its science program than did the control school. That was to be expected; the teachers of science in the experimental school had been formally introduced to the inquiry approach while those in the control school had not been introduced to inquiry to the same degree.

Comparability of the Individuals in the Groups

Kerlinger[42] states that complete variable control is not possible in ex post facto research. Matching subjects, however, can be used as a means toward countering this impossibility. In this study, variable control was attained by matching the students of the control group with those in the experimental group on a number of factors. Ideally, the students from the two groups should have been matched on all possible factors except on how they learned science. Or stated another way, the investigator attempted to match the subjects in the study so that they were comparable in every respect except for how they learned science. The variables on which the subjects were individually matched were: chronological age; I.Q. as measured by the California Short Form Test of Mental Maturity;[43] sex; and the socio-economic level according to Warner.[44] The investigator was able to make thirty matches which he considered to be valid. Those matches with relative data will be found in Appendix E. The mean age of the experimental group was ten years and eight months and

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[42]Kerlinger, Foundations of Behavioral Research, p. 361.

[43]Elizabeth T. Sullivan, Willis W. Clark, and Ernest W. Tiegs, California Short-Form Test of Mental Maturity (Monterey, Calif.: McGraw-Hill Publishers, 1963).

[44]W. Lloyd Warner, Marchia Meeker, and Kenneth Eells, Social Class in America: Manual of Procedure for the Measurement of Social Status (Harper Torchbook ed.; New York: Harper and Brothers, Publishers, 1960), pp. 121-158.

ten years and nine months for the control group. The mean I.Q. for both groups was 119 and the sex ratio in the matched comparison was eighteen females to twelve males. The socio-economic levels consisted of twenty-eight middle class and two upper class matches.

Method of Administering the Instrument

The Science process instrument was individually administered by the investigator to each subject in the study in the spring of 1971. The instrument was presented in two sessions with the second half presented about three weeks after the first half. These two sessions averaged one and one-half hours per subject. The first half of the instrument was administered to the experimental group in total before it was administered to the control group. Then the second half instrument was administered to the experimental group in total before it was administered to the control group. This procedure served two purposes; one, the investigator was not aware of how the individual student matches were proceeding and, two, each individually matched pair completed the tasks on the instrument at about the same time in the study.

The responses of the subjects were recorded on an especially designed answer sheet. Those responses for all subjects in both groups are found in Appendix F.

Method of Analyzing the Data

The raw data were compiled in the form of numerical scores for each subject. Those scores represented the number of acceptable responses made by the subject. In this manner seven scores were obtained for each subject; i.e., one for the total instrument and one each in observing, classifying, measuring, experimenting, interpreting, and predicting. Those scores are found in Appendix F.

The numerical scores were compiled so that differential comparisons could be made between each matched pair in the seven scoring areas just identified. Those individual differentiations were then totaled in comparing the two groups. A nonparametric statistical method was selected for analyzing the data in this study because several assumptions underlying the use of the parametric statistics could not be met. Chiefly, the shape of the population distribution and the population variance were unknown. Also, there was some question about the size of the sample being large enough to support parametric analysis.

The Wilcoxon matched-pairs signed-ranks test was selected for use in analyzing the data. Siegel[45] calls this test a most useful test for the behavioral scientist. Compared to the normal t-test, the Wilcoxon test has a

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[45] Sidney Siegel, Nonparametric Statistics for the Behavioral Sciences (New York: McGraw-Hill Book Company, 1956), p. 75.

power-efficiency of approximately 95%.[46] This means that in order to equate the powers of the two tests, ten cases must be obtained for the Wilcoxon analysis for every nine and one-half cases used in the t-test analysis.

The method for using the Wilcoxon test is as follows. The difference between the scores of each matched pair is ascertained and then ranked without regard to sign with the smallest numerical difference receiving the rank of one; after ranking, the signs of the differences are assigned to the ranks; the ranks are then totaled and the sum with the less frequent sign is used in the test; this smaller sum is referred to as T.[47]

The following formula was used in the cases where the sample sizes were larger than twenty-five.

$$Z = \frac{T - \frac{N(N+1)}{4}}{\sqrt{\frac{N(N+1)\ (2N+1)}{24}}}, \text{ where}$$

T represents the rank total with the less frequent sign and N is the sample size. Z is the standard score which was used to determine the probability level.

The probability for samples of 25 or less is determined directly from statistical tables. The T sum (the rank

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[46] *Ibid.*, p. 83.

[47] *Ibid.*, p. 76.

total with the less frequent sign) is found in the table and then the probability level is read directly from the table. One weakness in using those tables is the lack of exact probability listings.

The Level of Significance

The null hypotheses were tested at the 0.10 level of significance. This level was selected after considering the consequences of the possible decision errors. The following table summarizes the two types of errors which are possible whenever statistical decisions are made.

TABLE 1

TWO TYPES OF ERRORS*
(H_o = null hypothesis)

	Reject H_o	Accept H_o
H_o True	Type I Error (alpha probability)	Correct
H_o False	Correct	Type II Error (beta probability)

*After J. P. Guilford, <u>Fundamental Statistics in Psychology and Education</u> (New York: McGraw-Hill Book Co., 1965), p. 206.

It can readily be seen that a Type I error results when the null hypothesis is rejected when in fact it is true and that a Type II error results when the null hypothesis is accepted when in fact it is false. The possibilities for committing Type I errors will be decreased by using smaller significance levels because the possibility of rejecting the null hypothesis will be greatly reduced. In other words, there is less chance for rejecting the null hypothesis at an 0.01 level than at an 0.05 level. However, as the possibility for committing a Type I Error (alpha probability) is reduced, the chances for making a Type II Error (beta probability) are increased. That is, as the alpha size is decreased, the possibility of accepting a false null hypothesis is increased.

Guilford[48] calls for some kind of balance in setting the level of significance. He says there may be serious theoretical or practical reasons why it would be costly to make one kind of error or the other. Certain common-sense decisions should be reached regarding the relative seriousness of the consequences of making each type of error.

Within the context of this study, the investigator believed the consequences of a Type II Error were the more serious of the two. A Type I Error would mean the null hypothesis would be rejected when in fact it would be true. As a result, educators would believe the SCIS curriculum approach did influence the development of the learning processes in science and would possibly purchase the curriculum materials even though they would be of no value.

On the other hand, a Type II Error would mean the null hypothesis would be accepted when in fact it would not be true.

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[48]Guilford, Fundamental Statistics in Education and Psychology, p. 207.

As the result, educators would be reluctant to attempt the new curriculum approach even though it would be educationally beneficial to the students. Succinctly, a Type I Error at most, means wasted finances through the purchase of unnecessary curriculum materials. Conversely, a Type II Error means a beneficial pedagogical and educationally valuable approach might not be attempted. It is evident that a Type II Error will be more detrimental to the learner and education and is the consequence which should be avoided. A 0.10 level of significance will reduce the possibility of a Type II Error because of the inverse relationship[49] which exists between the occurrence of the decision errors; the larger significance levels will reduce the possibilities for committing the Type II Error.

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[49] Ibid., p. 206.

CHAPTER III

ANALYSIS AND DISCUSSION OF DATA

The Analysis

The data which were obtained in this study consisted of scores made by the subjects on the science process instrument. These scores were compiled in a manner which allowed the score differential to be ascertained for each matched subject pair. Stated another way, this compilation permitted the score differences to be observed for each matched pair in the study. These score differences were used in testing each of the hypotheses in the study. The Wilcoxon matched pairs signed ranks statistical test was used to test each of the hypotheses at the 0.10 level of significance.[50]

Analysis of the Total Test Responses

Major Null Hypothesis: No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to utilize science processes.

In this category 1020 acceptable responses were possible; the SCIS group scored 689 while the textbook group

[50] F. James Rohlf and Robert R. Sokal, Statistical Tables (San Francisco: W. H. Freeman and Company, 1969), p. 158.

scored 417. Those data are presented in Table 2.

The Wilcoxon treatment of the total responses produces a Z-score according to the equation:

$$Z = \frac{T - \frac{N(N + 1)}{4}}{\sqrt{\frac{N(N + 1)(2N + 1)}{24}}}$$, where: T = the sum of the lesser rank, in this case, 4.5, and N = the sample size, in this case, 30.

So: $$Z = \frac{4.5 - \frac{30(30 + 1)}{4}}{\sqrt{\frac{30(30 + 1)(2 \cdot 30 + 1)}{24}}}$$

$$Z = \frac{228.0}{49} = 4.65$$

$p(4.65) = 0.000002$

The results were significant at the 0.000002 level; consequently, the null hypothesis was rejected in favor of its alternate. The SCIS curriculum does significantly develop the student's ability to utilize science processes.

Analysis of the Responses for the Process of Observation

Subsidiary Null Hypothesis: No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to observe.

In this category 180 acceptable responses were possible; the SCIS group scored 114 while the textbook group scored 63. Those data are presented in Table 3.

TABLE 2

GROUP RESPONSES FOR THE TOTAL INSTRUMENT

Pair	Student Group		Score Difference	Rank of Difference	Rank with less frequent sign
	SCIS	Textbook			
1	32	18	14	24.0	
2	13	6	7	10.5	
3	23	13	10	18.5	
4	21	14	7	10.5	
5	29	13	16	27.5	
6	26	12	14	24.0	
7	10	12	-2	-1.0	1.0
8	24	21	3	3.5	
9	27	19	8	14.0	
10	21	11	10	18.5	
11	28	10	18	29.5	
12	31	16	15	26.0	
13	25	7	18	29.5	
14	19	13	6	7.5	
15	21	18	3	3.5	
16	23	20	3	3.5	
17	19	9	10	18.5	
18	20	11	9	16.0	
19	26	13	13	22.0	
20	18	11	7	10.5	
21	15	18	-3	-3.5	3.5
22	25	20	5	6.0	
23	28	16	12	21.0	
24	25	15	10	18.5	
25	20	14	6	7.5	
26	23	16	7	10.5	
27	21	13	8	14.0	
28	26	10	16	27.5	
29	28	14	14	24.0	
30	22	14	8	14.0	
Total	689	417		N = 30.0	T = 4.5

TABLE 3

GROUP RESPONSES FOR THE PROCESS--OBSERVATION

Pair	Student Group		Score Difference	Rank of Difference	Rank with less frequent sign
	SCIS	Textbook			
1	4	2	2	15.0	
2	3	1	2	15.0	
3	3	4	-1	-5.5	5.5
4	4	3	1	5.5	
5	6	1	5	26.5	
6	5	3	2	15.0	
7	3	3	0		
8	3	2	1	5.5	
9	6	1	5	26.5	
10	3	0	3	22.0	
11	4	3	1	5.5	
12	5	3	2	15.0	
13	3	2	1	5.5	
14	3	2	1	5.5	
15	4	4	0		
16	4	5	-1	-5.5	5.5
17	2	0	2	15.0	
18	3	2	1	5.5	
19	4	3	1	5.5	
20	3	1	2	15.0	
21	2	3	-1	-5.5	5.5
22	4	1	3	22.0	
23	4	4	0		
24	4	1	3	22.0	
25	4	1	3	22.0	
26	4	2	2	15.0	
27	4	0	4	25.0	
28	4	1	3	22.0	
29	4	2	2	15.0	
30	5	3	2	15.0	
Total	114	63		N = 27.0	T = 16.5

The Wilcoxon treatment of the responses in observation produces a Z-score according to the equation:

$$Z = \frac{T - \frac{N(N+1)}{4}}{\sqrt{\frac{N(N+1)(2N+1)}{24}}}, \text{ where } T = 16.5 \text{ and } N = 27.$$

So:

$$Z = \frac{16.5 - \frac{(27)(27+1)}{4}}{\sqrt{\frac{(27)(27+1)(2 \cdot 27+1)}{24}}}$$

$$Z = \frac{162.5}{42} = 3.88$$

$$p(3.88) = 0.000072$$

The results were significant at the 0.000072 level; consequently, the null hypothesis was rejected in favor of its alternate. The SCIS curriculum does significantly develop the student's ability to observe.

Analysis of the Responses for the Process of Classification

Subsidiary Null Hypothesis: No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to classify.

In this category 120 acceptable responses were possible; the SCIS group scored 103 while the textbook group scored 71. Those data are presented in Table 4.

TABLE 4

GROUP RESPONSES FOR THE PROCESS--CLASSIFICATION

Pair	Student Group		Score Difference	Rank of Difference	Rank with less frequent sign
	SCIS	Textbook			
1	4	2	2	16.5	
2	3	1	2	16.5	
3	4	4	0		
4	3	4	-1	-5.0	5.0
5	4	3	1	5.0	
6	4	2	2	16.5	
7	2	0	2	16.5	
8	2	4	-2	-16.5	16.5
9	4	3	1	5.0	
10	4	3	1	5.0	
11	4	2	2	16.5	
12	4	2	2	16.5	
13	4	1	3	24.0	
14	1	3	-2	-16.5	16.5
15	3	2	1	5.0	
16	3	2	1	5.0	
17	3	2	1	5.0	
18	2	2	0		
19	4	4	0		
20	4	2	2	16.5	
21	3	3	0		
22	4	4	0		
23	4	0	4	25.0	
24	4	3	1	5.0	
25	3	4	-1	-5.0	5.0
26	4	2	2	16.5	
27	4	2	2	16.5	
28	4	2	2	16.5	
29	4	2	2	16.5	
30	3	1	2	16.5	
Total	103	71		N = 25.0	T = 43.0

The Wilcoxon treatment of the responses in classification produces a Z-score according to the equation:

$$Z = \frac{T - \frac{N(N + 1)}{4}}{\sqrt{\frac{N(N + 1)(2N + 1)}{24}}}, \text{ where } T = 43 \text{ and } N = 25.$$

So:

$$Z = \frac{43 - \frac{25(25 + 1)}{4}}{\sqrt{\frac{25(25 + 1)(2 \cdot 25 + 1)}{24}}}$$

$$Z = \frac{119.5}{37} = 3.24$$

$$p(3.24) = 0.0007$$

The results were significant at the 0.0007 level; consequently, the null hypothesis was rejected in favor of its alternate. The SCIS curriculum does significantly develop the student's ability to classify.

Analysis of the Responses for the Process of Measurement

Subsidiary Null Hypothesis: No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to measure.

In this category 180 acceptable responses were possible; the SCIS group scored 104 while the textbook group scored 52. Those date are presented in Table 5.

TABLE 5

GROUP RESPONSES FOR THE PROCESS--MEASUREMENT

Pair	Student Group		Score Difference	Rank of Difference	Rank with less frequent sign
	SCIS	Textbook			
1	6	3	3	19.0	
2	0	1	-1	-3.5	3.5
3	4	0	4	22.5	
4	2	1	1	3.5	
5	5	0	5	26.0	
6	4	2	2	12.0	
7	0	3	-3	-19.0	19.0
8	3	2	1	3.5	
9	3	2	1	3.5	
10	4	0	4	22.5	
11	6	1	5	26.0	
12	6	2	4	22.5	
13	6	0	6	28.0	
14	2	2	0		
15	4	2	2	12.0	
16	6	4	2	12.0	
17	2	4	-2	-12.0	12.0
18	0	2	-2	-12.0	12.0
19	4	2	2	12.0	
20	1	3	-2	-12.0	12.0
21	2	2	0		
22	5	3	2	12.0	
23	4	2	2	12.0	
24	6	1	5	26.0	
25	3	0	3	19.0	
26	3	4	-1	-3.5	3.5
27	4	0	4	22.5	
28	3	1	2	12.0	
29	3	2	1	3.5	
30	3	1	2	12.0	
Total	104	52		N = 28.0	T = 62.0

The Wilcoxon treatment of the responses in measurement produces a Z-score according to the equation:

$$Z = \frac{T - \frac{N(N + 1)}{4}}{\sqrt{\frac{N(N + 1)(2N + 1)}{24}}}, \text{ where } T = 62 \text{ and } N = 28.$$

So:

$$Z = \frac{62 - \frac{(28)(28 + 1)}{4}}{\sqrt{\frac{28(28 + 1)(2 \cdot 28 + 1)}{24}}}$$

$$Z = \frac{141}{44} = 3.2$$

$$p(3.2) = 0.0007$$

The results were significant at the 0.0007 level; consequently, the null hypothesis was rejected in favor of its alternate. The SCIS curriculum does significantly develop the student's ability to measure.

Analysis of the Responses for the Process of Experimentation

Subsidiary Null Hypothesis: No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to experiment.

In this category 180 acceptable responses were possible; the SCIS group scored 124 while the textbook group scored 53. Those data are presented in Table 6.

TABLE 6

GROUP RESPONSES FOR THE PROCESS--EXPERIMENTATION

Pair	Student Group		Score Difference	Rank of Difference	Rank with less frequent sign
	SCIS	Textbook			
1	6	1	5	27.5	
2	3	0	3	18.0	
3	4	0	4	23.5	
4	4	0	4	23.5	
5	5	3	2	13.0	
6	6	0	6	29.0	
7	3	2	1	5.5	
8	5	4	1	5.5	
9	4	3	1	5.5	
10	3	2	1	5.5	
11	5	0	5	27.5	
12	6	3	3	18.0	
13	3	2	1	5.5	
14	4	2	2	13.0	
15	5	2	3	18.0	
16	0	1	-1	-5.5	5.5
17	3	2	1	5.5	
18	4	1	3	18.0	
19	5	1	4	23.5	
20	4	0	4	23.5	
21	4	3	1	5.5	
22	3	2	1	5.5	
23	5	3	2	13.0	
24	5	1	4	23.5	
25	3	4	-1	-5.5	5.5
26	3	1	-2	-13.0	13.0
27	4	2	2	13.0	
28	5	2	3	18.0	
29	6	2	4	23.5	
30	4	4	0		
Total	124	53		N = 29.0	T = 24.0

The Wilcoxon treatment of the responses in experimentation produces a Z-score according to the equation:

$$Z = \frac{T - \frac{N(N + 1)}{4}}{\sqrt{\frac{N(N + 1)(2N + 1)}{24}}}, \text{ where } T = 24 \text{ and } N = 29.$$

So:

$$Z = \frac{24 - \frac{29(29 + 1)}{4}}{\sqrt{\frac{29(29 + 1)(2 \cdot 29 + 1)}{24}}}$$

$$Z = \frac{193.5}{46} = 4.22$$

$$p(4.22) = 0.000013$$

The results were significant at the 0.000013 level; consequently, the null hypothesis was rejected in favor of its alternate. The SCIS curriculum does significantly develop the student's ability to experiment.

Analysis of the Responses for the Process of Interpretation

Subsidiary Null Hypothesis: No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to interpret.

In this category 180 acceptable responses were possible; the SCIS group scored 113 while the textbook group scored 97. Those data are presented in Table 7.

TABLE 7

GROUP RESPONSES FOR THE PROCESS--INTERPRETATION

Pair	Student Group		Score Difference	Rank of Difference	Rank with less frequent sign
	SCIS	Textbook			
1	6	5	1	5.5	
2	3	3	0		
3	2	4	-2	-13.0	13.0
4	3	2	1	5.5	
5	4	4	0		
6	2	3	-1	-5.5	5.5
7	2	2	0		
8	5	5	0		
9	4	6	-2	-13.0	13.0
10	4	2	2	13.0	
11	4	3	1	5.5	
12	4	4	0		
13	5	2	3	18.5	
14	5	2	3	18.5	
15	3	4	-1	-5.5	5.5
16	4	4	0		
17	3	2	1	5.5	
18	6	3	3	18.5	
19	5	2	3	18.5	
20	1	2	-1	-5.5	5.5
21	2	1	1	5.5	
22	5	5	0		
23	6	4	2	13.0	
24	3	4	-1	-5.5	5.5
25	2	5	-3	-18.5	18.5
26	4	4	0		
27	3	3	0		
28	4	2	2	13.0	
29	5	2	3	18.5	
30	4	3	1	5.5	
Total	113	97		N = 21.0	T = 66.5

The Wilcoxon test for small samples was used in this treatment because the sample size, N, after exclusion of the tied scores, was less than 25. In this treatment, the sum of the lesser signed rank, which is designated as T, is used in determining the significance level from a table of probabilities.

From Table 7, the sample size, N, is 21 and T is 66.5. Using these values with a table of critical values[51] for T, the probability level is found to be less than 0.05.

$$N = 21$$

$$T = 66.5$$

$$p(66.5) < 0.05$$

Consequently, the null hypothesis was rejected in favor of its alternate. The SCIS curriculum does significantly develop the student's ability to interpret.

Analysis of the Responses for the Process of Prediction

Subsidiary Null Hypothesis: No significant difference exists between the SCIS curriculum and the conventional textbook curriculum in developing the student's ability to predict.

In this category 180 acceptable responses were possible; the SCIS group scored 131 while the textbook group scored 79. Those data are presented in Table 8.

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[51]William H. Beyer, Handbook of Tables for Probability and Statistics (Cleveland, Ohio: Chemical Rubber Company, 1966), p. 309.

TABLE 8

GROUP RESPONSES FOR THE PROCESS--PREDICTION

Pair	Student Group		Score Difference	Rank of Difference	Rank with less frequent sign
	SCIS	Textbook			
1	6	5	1	3.5	
2	1	0	1	3.5	
3	6	1	5	27.5	
4	5	4	1	3.5	
5	5	2	3	19.5	
6	5	2	3	19.5	
7	0	2	-2	-11.5	11.5
8	6	4	2	11.5	
9	6	4	2	11.5	
10	3	4	-1	-3.5	3.5
11	5	0	5	27.5	
12	5	2	3	19.5	
13	5	0	5	27.5	
14	4	2	2	11.5	
15	2	4	-2	-11.5	11.5
16	6	4	2	11.5	
17	6	0	6	30.0	
18	5	1	4	24.0	
19	4	1	3	19.5	
20	5	3	2	11.5	
21	2	5	-3	-19.5	19.5
22	4	5	-1	-3.5	3.5
23	5	2	3	19.5	
24	3	5	-2	-11.5	11.5
25	5	0	5	27.5	
26	5	3	2	11.5	
27	2	6	-4	-24.0	24.0
28	6	2	4	24.0	
29	6	4	2	11.5	
30	3	2	1	3.5	
Total	131	79		N = 30.0	T = 85.0

The Wilcoxon treatment of the responses in prediction produces a Z-score according to the equation:

$$Z = \frac{T - \frac{N(N + 1)}{4}}{\sqrt{\frac{N(N + 1)(2N + 1)}{24}}}, \text{ where } T = 85 \text{ and } N = 30.$$

So: $$Z = \frac{85 - \frac{30(30 + 1)}{4}}{\sqrt{\frac{30(30 + 1)(2 \cdot 30 + 1)}{24}}}$$

$$Z = \frac{148}{49} = 3.02$$

$$p(3.02) = 0.0002$$

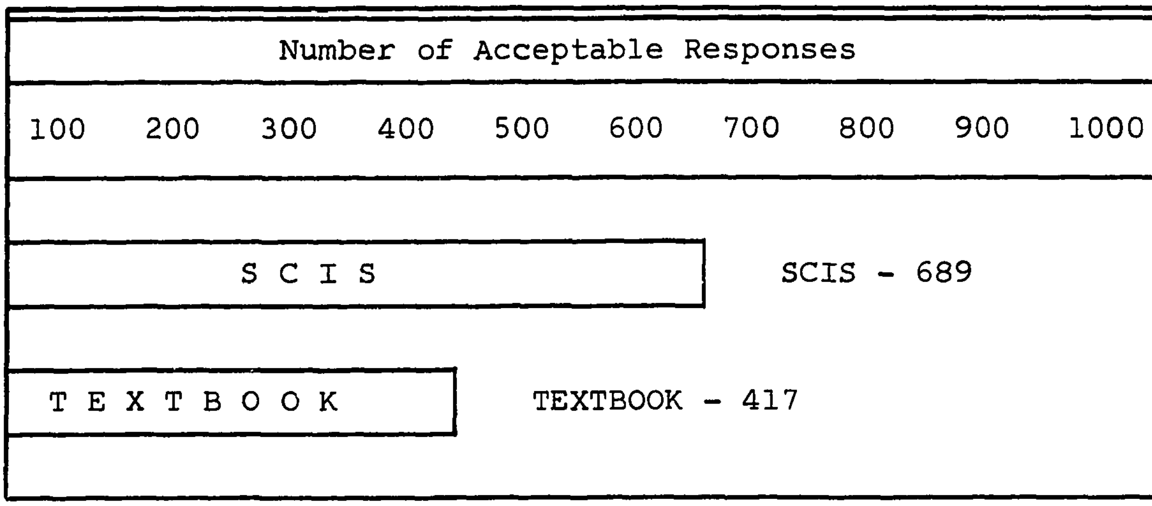
The results were significant at the 0.0002 level; consequently, the null hypothesis was rejected in favor of its alternate. The SCIS curriculum does significantly develop the student's ability to predict.

Discussion of Data

The seven hypotheses in this study were rejected in favor of the alternates. The most significant level of rejection was the comparison of the two groups on acceptable responses recorded for the total instrument. This comparison is graphically illustrated in Table 9.

TABLE 9

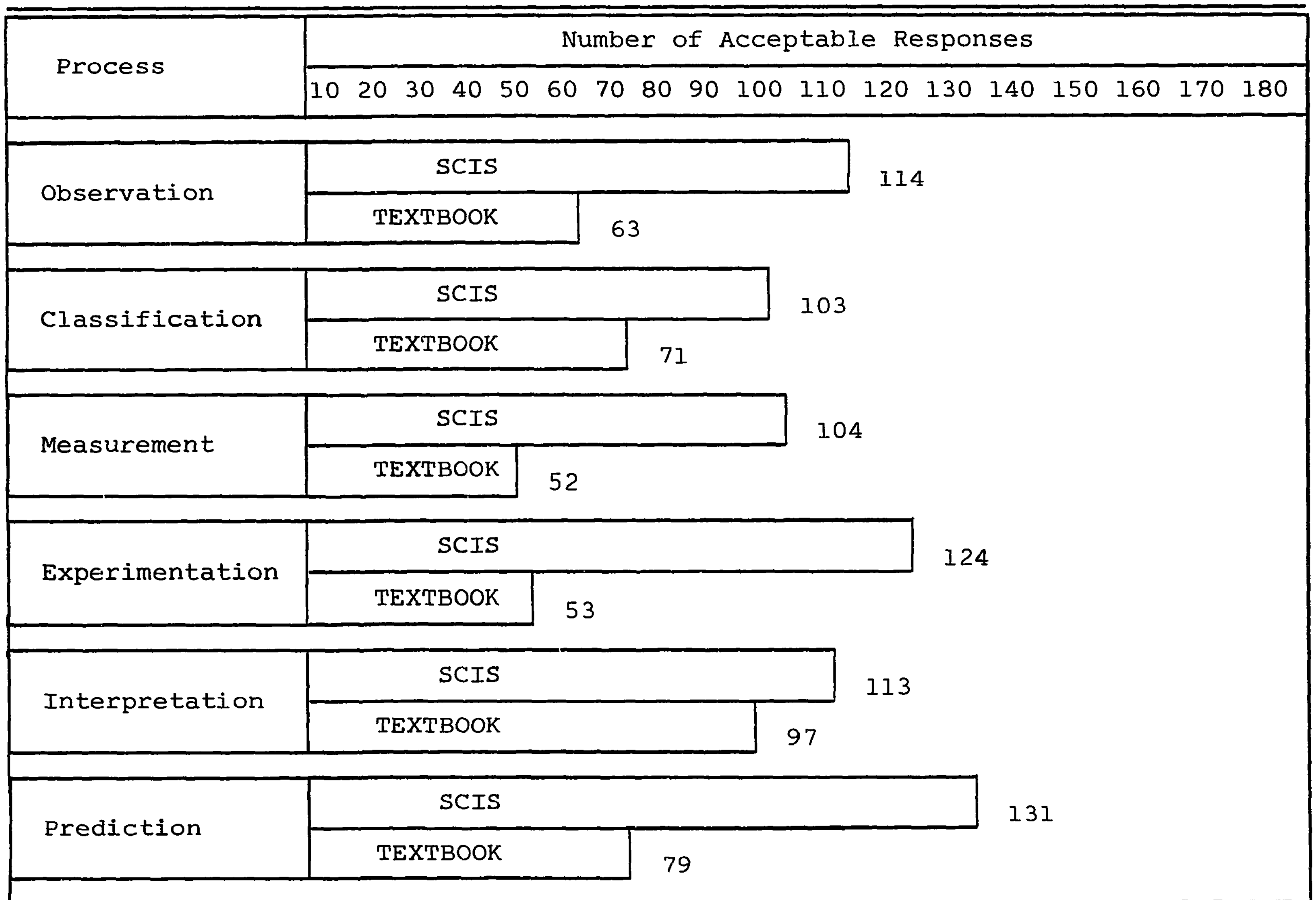
GRAPHIC PRESENTATION OF ACCEPTABLE GROUP RESPONSES FOR TOTAL INSTRUMENT



The total acceptable responses recorded for each group is broken into sub-totals for each of the six science processes and illustrated in Table 10. The data in this table represent the numerical scores attained by each group relative to the performance of the process tasks of the instrument.

TABLE 10

GRAPHIC PRESENTATION OF GROUP RESPONSES FOR EACH PROCESS



CHAPTER IV

CONCLUSIONS, COMMENTARY, AND RECOMMENDATIONS

Conclusions

This study was designed to assess the effectiveness, with respect to science process development, of the elementary science curriculum designed by the Science Curriculum Improvement Study. The assessment was made by comparing the performance of two groups of students on science process-oriented tasks. One group, the experimental group, had experienced only the SCIS curriculum since entering the first grade of school while the second group, the control group, had experienced only the textbook approach since entering the first grade. Because each group consisted of fifth grade students, each individual student had studied his respective science curriculum for nearly five years at the time the assessment was made.

The students in the comparisons were matched on the individual variables of sex, chronological age, intelligence level, and socio-economic level. Additionally, the two groups were selected from schools which were similar in their structural organization and in their curricular design. In essence, the educational experiences of the two groups of students were similar except for the way they had experienced science.

The investigator designed and validated the science process instrument which was used to make the assessment because such an instrument was not available commercially. The instrument assessed student performance on thirty-four tasks which required him to utilize the processes of observation, classification, measurement, experimentation, interpretation, and prediction.

The total number of acceptable responses which each student attained in each of the process areas and on the total instrument was tallied and compared to those responses of the matched member in the other group. Those comparisons were statistically analyzed, using the Wilcoxon matched pairs signed-ranks test, and the decision was then made whether to accept or to reject the null hypotheses of the study.

Each of the seven null hypotheses was rejected in favor of its alternate. The following alternate hypotheses were accepted.

1. The SCIS curriculum does significantly develop the student's ability to utilize science processes.

2. The SCIS curriculum does significantly develop the student's ability to observe.

3. The SCIS curriculum does significantly develop the student's ability to classify.

4. The SCIS curriculum does significantly develop the student's ability to measure.

5. The SCIS curriculum does significantly develop the student's ability to experiment.

6. The SCIS curriculum does significantly develop the student's ability to interpret.

7. The SCIS curriculum does significantly develop the student's ability to predict.

According to the logic of Chapter I, science is inquiry and the spirit of this inquiry reflects those processes identified in this study, i.e., observation, classification, measurement, experimentation, interpretation, and prediction. The results of this investigation indicate the SCIS curriculum is a superior program for teaching those processes. These findings plus the fact that both science educators and scientists participated in the development of the curriculum emphasize the value of the SCIS program. The investigator believes this program is educationally beneficial to the teaching of elementary school science.

Commentary

Some observations made by the investigator during the term of this study aren't identifiable in the recorded data. In other words, the recorded data and the statistical treatment do not reflect the subjective views of the investigator. These views were not recorded simply because there was no available mechanism within the research design which allowed this. However, the investigator believes some of these observations are significant enough to warrant inclusion here.

There was an observable disparity between the students in the two groups in the manner by which they approached the solutions of the tasks. The SCIS students were much more aggressive in their solution attempts. Some of those students literally "attacked" the materials involved in the task. By contrast, the textbook students were more passive in their approaches to performing the tasks. To illustrate this point, consider tasks 5-0 and 6-0; those tasks required the student to compare two clam shells. The student had available to him a spring balance, a ruler, a magnifier, and string. He had the equipment which permitted both qualitative and quantitative comparisons to be made. On several performances, the textbook students failed to actually touch and handle the shells. Such was not the case for the SCIS students. This difference between the student groups was evident throughout the testing procedure; i.e., the textbook students were more reluctant to get involved with the materials.

The students in the SCIS group appeared to be more diverse, persistent, and inventive in their designs toward performing the necessary operations required of each task. This observation has led the investigator to view the SCIS student as an individual who is more capable of operating where diverse mental approaches would be advantageous to learning, he is an individual who is not easily thwarted when confronted by a difficult task, and he is adroitly capable of attempting the technique and operational design necessary to solving a problem.

The observations in the above paragraph may identify another facet of the SCIS science curriculum--the encouragement of creative expression. The investigator believes the general approach of the SCIS group reflects the individual student's ability to create constructive designs and solutions to problems with which he is confronted.

This investigation has provided an initial step toward alleviating at least one problem which has impeded the progressive implementation of inquiry approaches in our schools. One of the most difficult problems has been the question of how to evaluate the inquiry process. The development of the science process instrument in this study should provide future direction in this area of evaluation.

Recommendations

Several recommendations are presented to those who are interested in the results of this study. These recommendations are based on the results of the study and the investigator's observations and involvement during the investigation.

1. The results of this study clearly indicate the SCIS curriculum is superior to the textbook-centered curriculum in developing the student's ability to observe, classify, measure, experiment, interpret, and predict. Because these are the same processes on which science activity is based, it

behooves all schools to critically examine the possible inclusion of the SCIS program in the science curriculum. Those processes identified above are also the same or at least they closely complement those rational powers which the Educational Policies Commission identified in 1961 as being vital to developing the thinking processes of the learner.[52] This, then, is also a factor favoring the implementation of the SCIS program in the elementary school.

2. An expanded replication of this study would provide a broader basis for making conclusions. The investigator recommends a larger, diverse population be selected at different grade levels for inclusion in such a study. This expanded approach would permit comparisons to be made between the variables of sex, intelligence levels, and socio-economic levels between students who have studied SCIS science and those who have not.

3. The investigator also recommends future study of the SCIS curriculum's possible influence on the learner's development of creative expression. The observations made in this study seem to reflect a possible correlation between the successful performance of process-oriented tasks and creative expression.

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[52]Educational Policies Commission, The Central Purpose of American Education, (Washington, D.C.: National Education Association, 1961).

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APPENDIX A

THE SCIENCE PROCESS INSTRUMENT

SCORE SHEET

Name________________________ Grade Level________________

School______________________ Teacher____________________

	Acceptable	Unacceptable		Acceptable	Unacceptable
1-0			18-E		
2-0			19-E		
3-0			20-E		
4-0			21-E		
5-0			22-E		
6-0			23-I		
7-C			24-I		
8-C			25-I		
9-C			26-I		
10-C			27-I		
11-M			28-I		
12-M			29-P		
13-M			30-P		
14-M			31-P		
15-M			32-P		
16-M			33-P		
17-E			34-P		

PROCESS DEFINITIONS

The following definitions have been constructed to identify the processes which the tasks have been designed to assess. The reader must understand that each definition is specific to the process as it is used in this instrument.

Observing. The process through which information is obtained, either directly or indirectly, with the intent of understanding more about an object or situation. This process is based on the utilization of the five senses--seeing, touching, hearing, smelling, and tasting, either partially or in totality in any specific situation.

Classifying. The process of mentally or physically placing objects in groups which have systematic relationships. These relationships can occur among the objects of a specific group and among or between groups.

Measuring. The process of obtaining the dimensions of an object by comparing the object to a standard unit. Any selected unit can serve as this standard.

Experimenting. The process of recognizing and controlling variables while doing something in an attempt to solve a problem. The problem can be externally designed and presented to the experimenter or the problem can be structured internally by the experimenter.

Interpreting. The process of searching for a meaningful understanding in accumulated data with the intent of utilizing the understanding in answering questions relative to the data.

Predicting. The process of foretelling the behavior of an event from the available data which is currently at hand.

PROCESS--OBSERVING

Task 1. Nos. 1-0 and 2-0.

Materials:	A piece of clear, transparent plastic 8 1/2 X 5 1/4 inches.
Administrative Procedure:	Give the plastic to the child.
Instructions to the child:	Describe this object.
Score:	1-0. Place a check in the acceptable column if four properties are given.
	2-0. Place a check in the acceptable column if eight or more properties are given.

Task 2. Nos. 3-0 and 4-0.

Materials:	Ten pieces of chalk, four marbles, three ping pong balls, five dominoes, three wooden cubes, four nails, two identical boxes (cigar).
Administrative Procedure:	One of the empty boxes is sealed with three pieces of chalk in it. Place this box in front of the child. Place the objects and the other empty, opened box in front of the child.
Instructions to the child:	What is in this sealed box? (The administrator will just point to the sealed box.)
Score:	3-0. Place a check in the acceptable column if the child manipulates the sealed box before he attempts to make the identification.
	4-0. Place a check in the acceptable column if the child attempts to use the empty box and the objects to identify what is in the sealed box.

Task 3. Nos. 5-O and 6-O.

Materials:	Magnifier, ruler, a piece of string, two sea shells (different), a spring balance.
Administrative Procedure:	Give the materials to the child.
Instructions to the child:	Tell how these two shells are different.
Score:	5-O. Place a check in the acceptable column if the child gives four qualitative differences (non-measured, non-numbered).
	6-O. Place a check in the acceptable column if the child gives two quantitative differences (measured, numbered).

PROCESS--CLASSIFYING

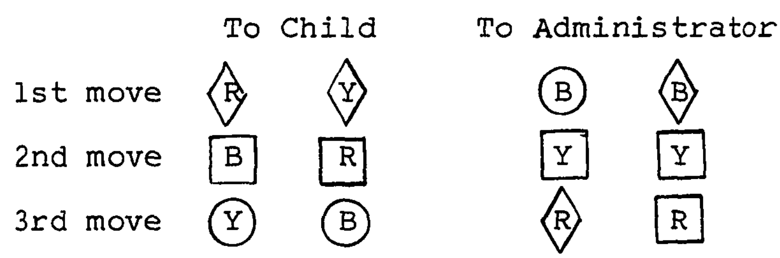
Task 4. Nos. 7-C and 8-C.

Materials:	A collection of the following objects: two nails, one plastic spoon, 4 X 4 inch aluminum foil, four marbles, one thumb tack, one wooden pencil, one index card (3 X 5 inches).
Administrative Procedure:	Give the collection of objects to the child.
Instructions to the child:	Place these objects in groups so that the objects in each group are alike in some way and tell how they are alike.
Score:	7-C. Place a check in the acceptable column if the child places all the objects in logical groups.
	8-C. Place a check in the acceptable column if the child properly identifies the characteristic of each group.

Task 5. Nos. 9-C and 10-C.

Materials: Cards cut in these designs: six red diamonds, six blue diamonds, six yellow diamonds, six red circles, six blue circles, six yellow circles, six red rectangles, six blue rectangles, six yellow rectangles.

Administrative Procedures: The cards will be placed in a pile in front of the child and the administrator will begin and control the initial part of the activity. With the appropriate instructions he will give a set of two cards to the child and then give a set of two cards to himself. The administrator will do this for a total of three moves. The following pattern will be followed:



After the administrator has completed the third move, the child will be asked to select from the card pile, two cards for himself and two cards for the administrator.

Instructions to the child: I am going to give you two cards and then give myself two cards. I will do this in a special way. Here is your first pair of cards and here is my first pair of cards. Here is your next pair and here is my next pair. Here is your third pair and here is my third pair. Now, you give yourself two cards and then give me two cards. Do this in the same special way which I did.

Score:

9-C. Place a check in the acceptable column if the child gives himself either two of the same shape or two of a different color.

10-C. Place a check in the acceptable column if the child gives the administrator two of the same color.

PROCESS--MEASURING

Task 6. Nos. 11-M and 12-M.

Materials: A collection of the following: a strip of paper two inches by one-half inch, a marble, a nail, a button and twelve beans, and a 3 X 5 inch card. (No ruler).

Administrative Procedure: Give the collection to the child. After he examines them, give him the 3 x 5 card.

Instructions to the child: Measure the length of this card.

Score: 11-M. Place a check in the acceptable column if the child attempts to use any of the objects to measure the card's length.

12-M. Place a check in the acceptable column if the child actually gives a measurement. Example--3 1/2 nails long.

Task 7. Nos. 13-M and 14-M.

Materials: Tripod support, stiff wire, a rubber band, a sheet of graph paper, 1/2 oz. fishing weights, and a large nut (a threaded head of a bolt).

Administrative Procedure: Give the objects to the child and then hand him the nut.

Instructions to the child: What is the weight of this object? Use any of these objects if you want to. These fishing weights weigh 1/2 oz. each.

Score: 13-M. Place a check in the acceptable column if the child attempts to calibrate the rubber band stretch with the 1/2 oz. weights.

14-M. Place a check in the acceptable column if the child gives the weight of the nut as between 2-4 ounces.

Task 8. Nos. 15-M and 16-M.

Materials: Four 3 X 5 inch blank index cards with one each painted red, yellow, blue, and green, a small metric-scale ruler.

Administrative Procedure: The four cards must be of identical length but each painted a different color. The metric ruler should be in the 160 mm class or larger.

Instructions to the child: Measure these cards and determine how many little marks each card is long and how many little marks each card is wide.

Score: 15-M. Place a check in the acceptable column if the child gives the length of each card as identical--127 marks.

16-M. Place a check in the acceptable column if the child gives the width of each card as identical--76 marks.

PROCESS--EXPERIMENTING

Task 9. Nos. 17-E and 18-E.

Materials: Solutions of salt water (A), water with phenolphthalien (B), and distilled water (C). The following dry powders: lead nitrate (1), calcium oxide (2), and sodium chloride (3). Straws to serve as droppers and scoops. Wax paper on which to mix. Powder papers and small paper cups to hold the liquids.

Administrative Procedure: The solutions and the powders must be prepared before the test administration. Give the child about 25 ml of each solution and 5 grams of each powder. Also, a sheet of wax paper should be given for the mixing. The straws, cups, and powder papers should be discarded after each child is tested. In placing the materials before the child, make it a point not to order them, i.e., 1, 2, and 3 or A, B, and C.

Instructions to the child: A red color will be formed when one of these liquids and one of these powders are mixed. Find which two will give the color.

Score: 17-E. Place a check in the acceptable column if the child approaches the task in a systematic manner, i.e., put powder 1 in liquid A, B, C, etc.

18-E. Place a check in the acceptable column if the child finds powder 2 and liquid B will give the red color.

Task 10. Nos. 19-E and 20-E.

Materials: A piece of cotton material (3 X 10 inches), a piece of knit material (3 X 10 inches), four containers, a source of time measurement, a ruler, and water.

Administrative Procedure: The materials are given to the child.

Instructions to the child: Which of these pieces of cloth will soak up water faster? Tell what you would do in finding out.

Score: 19-E. Place a check in the acceptable column if the child gives two of the following:

___Put the same length of each cloth in water.
___Keep them in the water for the same length of time.
___See how far the water moves on each cloth.
___Use water of the same temperature.
___Use same amount of water.

Instructions to the child: Go ahead and see if the cloth you selected does soak up water faster.

Score: 20-E. Place a check in the acceptable column if the child approaches the task in a systematic manner, i.e., controls the variables as he listed in 19-E.

Task 11. Nos. 21-E and 22-E.

Materials: Ruler, string, scissors, support stand, wire, washers, three lens, three index cards, three rubber stoppers, and three marbles.

Administrative Procedure: The collection of materials is given to the child. The objective is to see whether the child can utilize them in some experimental design.

Instructions to the child: Here are some things. Use them and work an experiment of some kind. Do anything you wish. I will be asking you some questions about your experiment in five minutes or before if you finish your experiment.

Score:

21-E. Place a check in the acceptable column if the child does <u>all</u> the following:

___Identifies an experimental problem. (What is the name of your experiment?)
___Sets up the materials in an attempt to solve the problem. (What did you do in your experiment?)
___Shows a concern for the necessity of controlling the variables.

22-E. Place a check in the acceptable column if the child does <u>all</u> the following:

___Attempts to hold some variables constant.
___Actually arrives at some data.
___Offers a possible solution based on his data.

PROCESS--INTERPRETING

Task 12. Nos. 23-I and 24-I.

Materials: Four microscope slides and four water solutions of sodium chloride for each child.

Administrative Procedure: The day before the task, the four slides must be prepared to insure the water will be evaporated.

Slide	Liquid	Water	Sodium Chloride
A	A	250 ml	1 tsp.
B	B	250 ml	5 tsp.
C	C	250 ml	3 tsp.
D	D	250 ml	10 tsp.

Instructions to the child: These liquids were made by putting salt in water. Each bottle has a different amount of salt. These glass slides were prepared by placing a drop of liquid on the glass. The letter on the glass slide tells which bottle of liquid it came from. Which liquid has the most salt in it?

Score: 23-I. Place a check in the acceptable column if the child attempts to correlate the amount of salt on the slide with the liquids.

24-I. Place a check in the acceptable column if the child determines liquid D has the most salt.

Task 13. Nos. 25-I and 26-I.

Materials: See attached graph.

Administrative Procedure: Give the graph to the child.

Instructions to the child: After a windstorm, a science class went out to a flower patch to see how much the flowers were damaged. Each child picked one flower and counted the petals which the flower still had. They made a graph showing the number of petals which the flowers had. Give the graph to the child. I will ask you some questions.

Score: 25-I. Place a check in the acceptable column if the child answers the following correctly:

___What is the smallest number of petals in any flower? Ans. (1).

___What was the number of petals which was most often found on the flowers? Ans. (5).

26-I. Place a check in the acceptable column if the child answers the following correctly:

___ What number of flowers had seven petals? Ans. (5).

___ How many students are in the class? Ans. (38).

Task 14. Nos. 27-I and 28-I.

Materials: A 100 ml graduated cylinder, six marbles, and water.

Administrative Procedure: Give the materials to the child with the cylinder filled to the 50 ml mark.

Instructions to the child: When you place these marbles in the water, the water level will rise. Put these marbles in the water, two at a time and write down how many marks the water level rises each time. Do this until all six marbles are in the water. I will ask you some questions when you finish.

Score: 27-I. Place a check in the acceptable column if the child answers correctly from his data this question--Does the water level rise the same amount each time two marbles are placed in the water?

28-I. Place a check in the acceptable column if the child answers correctly from his data this question--How many marks would the water level rise if just three marbles are added to the water?

PROCESS--PREDICTING

Task 15. Nos. 29-P and 30-P.

Materials: A rubber band, a small piece of stiff wire, a support stand, a ruler, graph paper, and four washers.

Administrative Procedure: Give the materials to the child.

Instructions to the child: You have four washers here. How far will eight washers stretch this rubber band? I will ask you to tell how you found out.

Score: 29-P. Place a check in the acceptable column if the child determines how far the four washers will stretch the rubber band.

30-P. Place a check in the acceptable column if the child gives an answer for the stretch of eight washers as based on his data.

Instructions to the child: How did you find out?

Task 16. Nos. 31-P and 32-P.

Materials: A pendulum and support, a ruler, and a timer or watch for administration.

Administrative Procedure: The pendulum is set up and its nature explained to the child. The administrator will adjust the pendulum's length at 20 inches. The child will count the swings for one half-minute. The pendulum will then be adjusted to 10 inches and the child will again count the swings for one-half minute. The administrator will do the timing.

Instructions to the child: How many swings will the pendulum make in one half minute if we were to shorten the length to five inches?

Score: 31-P. Place a check in the acceptable column if the child makes a prediction based on his data from both the 20 inch and 10 inch lengths.

Say to the child: Will you now check how accurate your answer was to the five inch pendulum length?

Score: 32-P. Place a check in the acceptable column if the child shortens the pendulum length to five inches and counts the swings in one-half minute.

Task 17. Nos. 33-P and 34-P.

Materials: Three different kinds of rubber balls (different in diameter, color, etc.).

Administrative Procedure: The three balls are given to the child.

Instructions to the child: Here are three rubber balls. You can do anything with them that you wish except bounce them. Decide which one will bounce higher when dropped from the same height.

Score: 33-P. Place a check in the acceptable column if the child manipulates the three rubber balls to obtain data of some kind from which his prediction was made.

34-P. Place a check in the acceptable column if the child makes an accurate prediction based on his data.

APPENDIX B

INSTRUMENT RELIABILITY

Instrument Reliability Data

The reliability coefficient was determined by the split-half method according to Rulon as presented by Magnusson.[52] This method utilizes the following formula:

$$rtt = 1 - s^2d/s^2t$$

where rtt is the reliability coefficient and s^2d is the variance between the individual scores obtained from the two test halves. The symbol for the total variance between all totaled scores from the test halves is s^2t.

The data obtained from the twenty Weatherford subjects are found in Table 11. The X and Y columns represent the two half-test scores. The half-test items were determined by random selection in an attempt to achieve comparable difficulty between the halves. The dj column is the difference between the two half-test scores. This difference, squared, is found in the column labeled d^2j. The total student score is in the column labeled tj with the square of this score in the column, t^2j.

The individual score variance is determined by the equation:

$$s^2d = \frac{d^2j}{N} - \left(\frac{dj}{N}\right)^2 .$$

In the equation, s^2d, the individual score variance, is equal to the total squared half-test score differences divided by the number of subjects, $\frac{170}{20}$. Subtracted from this is the

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[52]Magnusson, <u>Test Theory</u>, p. 111.

total half-test score differences which are divided by the number of subjects and then squared, $\left(\frac{46}{20}\right)^2$. Thus:

$$s^2d = \frac{d^2j}{N} - \left(\frac{dj}{N}\right)^2 = \frac{170}{20} - \left(\frac{46}{20}\right)^2 = 3.21$$

The total score variance, s^2t, is determined by the equation:

$$s^2t = \frac{t^2j}{N} - \left(\frac{tj}{N}\right)^2.$$

In the foregoing equation, the sum of the student scores squared, t^2j, is divided by the number of subjects, N, i.e., $\frac{4382}{20}$. Subtracted from this is the total of the student scores, tj, which is divided by the number of subjects, N, and then squared, $\left(\frac{290}{20}\right)^2$. Thus:

$$s^2t = \frac{t^2j}{N} - \left(\frac{tj}{N}\right)^2 = \frac{4382}{20} - \left(\frac{290}{20}\right)^2 = 8.85$$

The reliability coefficient is then determined by the formula:

$$rtt = 1 - \frac{s^2d}{s^2t}$$

$$= 1 - \frac{3.21}{8.85}$$

$$rtt = 0.64$$

TABLE 11

DATA USED IN RELIABILITY DETERMINATION

Student	X Half	Y Half	dj	d^2j	tj	t^2j
1.	6	6	0	0	12	144
2.	5	9	-4	16	14	196
3.	11	10	1	1	21	441
4.	8	10	-2	4	18	324
5.	7	5	2	4	12	144
6.	2	10	-8	64	12	144
7.	9	8	1	1	17	289
8.	7	8	-1	1	15	225
9.	3	7	-4	16	10	100
10.	3	6	-3	9	9	81
11.	9	10	-1	1	19	361
12.	5	8	-3	9	13	169
13.	4	8	-4	16	12	144
14.	7	9	-2	4	16	256
15.	6	9	-3	9	15	225
16.	6	7	-1	1	13	169
17.	7	10	-3	9	17	289
18.	8	9	-1	1	17	289
19.	7	7	0	0	14	196
20.	6	8	-2	4	14	196
		Totals	46	170	290	4382

APPENDIX C

INSTRUMENT VALIDITY

Instrument Validity Data

The method followed in determining the instrument's validity was to use a proportions statistical test in determining the significance of the panel's choices. The formula used in the treatment was:

$$Z = \frac{p - P}{\sqrt{\frac{PQ}{N}}}$$

where the Z score is determined by subtracting the probability based on chance, P, from the observed probability, p, and dividing by the standard deviation of the probability distribution, $\sqrt{\frac{PQ}{N}}$.

The panel's ratings are tabulated in Table 12. Fifty-nine of the possible sixty-eight ratings are at the highly representative or the excellent level. Only eight ratings are as low as the suitable category while one is rated as not-representative. In other words, 87% of the tasks were rated as excellent or highly representative by the panel of experts.

Table 13 contains the delineated results of the statistical treatment of the panel's rating choices. The following explanations are provided to aid the reader in understanding how the values were obtained. The M column contains the number of actual choices made for each specific rating, i.e., 30 choices were rated as excellent. The P column gives the probability possible by chance which in this case is 0.25

TABLE 12

PANEL RATINGS FOR VALIDATION

Task No.	Davis				Berkheimer				Butts				Fishleder			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1		x					x				x			x		
2		x			x					x				x		
3		x				x			x					x		
4		x			x				x					x		
5	x					x			x					x		
6	x				x					x				x		
7	x						x		x					x		
8	x					x			x				x			
9	x				x				x					x		
10	x					x					x			x		
11		x				x					x			x		
12	x				x					x				x		
13	x						x		x					x		
14	x				x				x						x	
15	x					x			x				x			
16		x			x				x					x		
17				x		x			x						x	

1 = Excellent

2 = Highly Representative

3 = Suitable

4 = Not Representative

TOTALS = 30 Excellent

29 Highly Representative

8 Suitable

1 Not Representative

TABLE 13

STATISTICAL TREATMENT OF RATINGS

Rating Choices	M	P	p	p-P	$\sqrt{\frac{PQ}{N}}$	$Z = \frac{p-P}{\sqrt{\frac{PQ}{N}}}$	Probability of Choices
Excellent	30	0.250	0.441	0.191	0.055	3.47	0.0003
Highly Representative	29	0.250	0.426	0.176	0.055	3.20	0.0007
Suitable	8	0.250	0.118	-0.132	0.055	2.40	0.0082
Not Representative	1	0.250	0.015	-0.235	0.055	4.29	0.000013

N = 68 possible choices on total instrument.

M ==Number of choices for a specific rating.

P = Probability of chance.

p = Observed probability $\left(\frac{\text{Number of actual choices}}{\text{Number of possible choices}}\right)$

$\sqrt{\frac{PQ}{N}}$ = Standard deviation of the probability distribution.

$\frac{p-P}{\sqrt{\frac{PQ}{N}}}$ = Z score because each rating had the chance of one in four of being chosen. The observed probability in column p is determined by dividing the actual number of choices by the total possible choices. For the excellent rating, the actual number of choices is divided by the 68 possible choices giving an observed probability of 0.441. The column, p-P, is found by subtracting the chance probability from the observed probability, which for the excellent rating would be 0.441 - 0.250 = 0.191. The standard deviation of the probability distribution in the column labeled $\sqrt{\frac{PQ}{N}}$ is determined by taking the square root $\frac{PQ}{N}$ where P is the chance probability, 0.250, and Q is equal to 1 - P or 1 - 0.250 = 0.750. The total possible number of choices, N, is 68. Thus:

$$\sqrt{\frac{PQ}{N}} = \sqrt{\frac{(0.250)(0.750)}{68}} = 0.055.$$

The Z score is then determined by dividing p - P by $\sqrt{\frac{PQ}{N}}$. The probability is ascertained by locating that Z score value in any standard table of statistical probabilities.

APPENDIX D

INSTRUMENT DISCRIMINATORY POWER

TABLE 14

P-SCORE COMPUTATIONS*

Observing	--	$\frac{41}{120}$	acceptable responses / possible responses = 0.34
Classifying	--	$\frac{51}{80}$	acceptable responses / possible responses = 0.64
Measuring	--	$\frac{42}{120}$	acceptable responses / possible responses = 0.35
Experimenting	--	$\frac{30}{120}$	acceptable responses / possible responses = 0.25
Interpretation	--	$\frac{46}{120}$	acceptable responses / possible responses = 0.38
Prediction	--	$\frac{80}{120}$	acceptable responses / possible responses = 0.67
Total Instrument	--	$\frac{290}{680}$	acceptable responses / possible responses = 0.43

*The P-score is defined as the frequency of acceptable responses scored on the process tasks.

TABLE 15

RESPONSES OF THE PRELIMINARY WEATHERFORD TEST

O = Observation M = Measurement I = Interpretation
C = Classification E = Experimentation P = Prediction

Student	O 1	O 2	O 3	O 4	O 5	O 6	C 7	C 8	C 9	C 10	M 11	M 12	M 13	M 14	M 15	M 16
1	1	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0
2	1	0	0	0	1	0	0	0	1	1	0	0	0	1	0	1
3	1	0	0	0	1	0	1	1	1	1	1	1	1	1	1	1
4	1	0	1	0	1	0	0	0	0	0	1	1	0	1	1	1
5	1	0	1	0	1	0	1	1	0	0	1	0	0	0	0	0
6	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0
7	1	0	0	0	1	0	1	1	1	1	1	1	0	1	0	0
8	1	0	1	0	1	0	1	1	1	1	1	1	0	1	0	0
9	1	0	1	0	1	0	0	0	1	0	0	0	0	0	1	1
10	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0

TABLE 15--(Continued)

Student	O 1	O 2	O 3	O 4	O 5	O 6	C 7	C 8	C 9	C 10	M 11	M 12	M 13	M 14	M 15	M 16
11	1	0	1	0	1	1	1	1	1	0	1	1	0	0	0	0
12	1	0	0	0	1	0	1	1	1	1	0	0	0	0	0	0
13	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0
14	1	0	1	0	1	0	1	1	0	1	0	0	0	1	0	0
15	1	0	0	0	1	0	1	1	1	0	1	0	1	0	0	0
16	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1
17	0	0	0	0	1	0	1	1	1	1	1	1	0	1	0	0
18	1	0	0	0	1	0	1	1	1	1	1	1	0	1	0	0
19	1	0	0	0	1	0	1	1	0	0	1	0	0	1	1	1
20	1	0	0	0	0	0	1	1	0	1	0	0	0	1	0	0

TABLE 15--(Continued)

Student	E 17	E 18	E 19	E 20	E 21	E 22	I 23	I 24	I 25	I 26	I 27	I 28	I 29	P 30	P 31	P 32	P 33	P 34
1	1	0	1	0	0	0	0	0	0	0	1	0	1	1	1	1	1	0
2	0	1	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	0
3	0	1	0	0	0	0	1	1	0	1	1	1	1	1	0	0	1	0
4	1	1	1	0	0	0	1	1	1	0	0	0	1	1	0	0	1	1
5	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1
6	0	1	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1
7	1	1	1	0	0	0	1	1	0	0	0	0	0	0	1	1	1	1
8	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1	0
9	0	0	0	0	0	0	1	1	0	0	1	0	0	0	1	0	0	0
10	0	1	0	0	0	0	0	p	0	0	1	0	1	1	0	1	0	1

TABLE 15--(Continued)

Student	E 17	E 18	E 19	E 20	E 21	E 22	I 23	I 24	I 25	I 26	I 27	I 28	P 29	P 30	P 31	P 32	P 33	P 34
11	1	1	1	0	0	0	1	1	0	0	0	0	1	1	1	1	1	0
12	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1	1	1	1
13	0	1	0	0	0	0	1	1	0	0	0	0	1	0	1	1	1	1
14	0	1	1	0	0	0	1	1	0	0	0	1	0	0	1	1	1	1
15	0	1	0	0	0	0	1	1	0	0	0	0	1	1	1	1	1	1
16	1	1	0	0	0	0	1	1	0	0	0	1	1	1	0	0	1	1
17	1	1	0	0	0	0	1	1	0	0	1	0	0	0	1	1	1	1
18	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1
19	0	1	0	0	0	0	1	1	1	0	0	1	0	0	0	1	0	0
20	1	1	0	0	0	0	1	1	0	0	0	0	1	0	1	1	1	1

APPENDIX E

CHARACTERISTICS OF MATCHED PAIRS USED IN STUDY

TABLE 16

MATCHED PAIRS USED IN STUDY

Pair	Student	Sex	Age	I.Q.	Socio-economic Level
1	Experimental	M	126 months	134	Upper
	Control	M	131 months	129	Upper
2	Experimental	F	131 months	86	Middle
	Control	F	135 months	80	Middle
3	Experimental	F	133 months	131	Middle
	Control	F	130 months	126	Middle
4	Experimental	F	132 months	125	Middle
	Control	F	128 months	128	Middle
5	Experimental	M	123 months	133	Middle
	Control	M	124 months	140	Middle
6	Experimental	M	130 months	115	Middle
	Control	M	128 months	121	Middle
7	Experimental	F	128 months	107	Middle
	Control	F	128 months	106	Middle
8	Experimental	M	123 months	129	Middle
	Control	M	124 months	127	Middle
9	Experimental	M	124 months	118	Middle
	Control	M	129 months	116	Middle
10	Experimental	M	125 months	125	Upper
	Control	M	128 months	125	Upper

TABLE 16--(Continued)

Pair	Student	Sex	Age	I.Q.	Socio-economic Level
11	Experimental	M	135 months	110	Middle
	Control	M	133 months	101	Middle
12	Experimental	M	140 months	102	Middle
	Control	M	138 months	98	Middle
13	Experimental	F	133 months	118	Middle
	Control	F	134 months	118	Middle
14	Experimental	F	126 months	113	Middle
	Control	F	128 months	114	Middle
15	Experimental	F	129 months	108	Middle
	Control	F	130 months	101	Middle
16	Experimental	M	130 months	107	Middle
	Control	M	126 months	104	Middle
17	Experimental	F	124 months	113	Middle
	Control	F	123 months	114	Middle
18	Experimental	F	133 months	127	Middle
	Control	F	137 months	132	Middle
19	Experimental	F	134 months	118	Middle
	Control	F	131 months	121	Middle
20	Experimental	F	127 months	102	Middle
	Control	F	125 months	106	Middle

TABLE 16--(Continued)

Pair	Student	Sex	Age	I.Q.	Socio-economic Level
21	Experimental	M	123 months	103	Middle
	Control	M	125 months	106	Middle
22	Experimental	F	123 months	118	Middle
	Control	F	126 months	118	Middle
23	Experimental	M	134 months	133	Middle
	Control	M	131 months	138	Middle
24	Experimental	F	123 months	120	Middle
	Control	F	123 months	121	Middle
25	Experimental	F	126 months	112	Middle
	Control	F	128 months	118	Middle
26	Experimental	M	132 months	107	Middle
	Control	M	132 months	100	Middle
27	Experimental	F	123 months	115	Middle
	Control	F	124 months	115	Middle
28	Experimental	F	134 months	101	Middle
	Control	F	133 months	102	Middle
29	Experimental	M	127 months	104	Middle
	Control	M	129 months	99	Middle
30	Experimental	F	131 months	114	Middle
	Control	F	131 months	114	Middle

APPENDIX F

TOTAL SUBJECT RESPONSES MADE ON PROCESS INSTRUMENT

TABLE 17

RESPONSES MADE BY STUDENTS ON PROCESS INSTRUMENT

O = Observation   M = Measurement   I = Interpretation
C = Classification   E = Experimentation   P = Prediction

Pair	Student	1-O	2-O	3-O	4-O	5-O	6-O	7-C	8-C	9-C	10-C	11-M
1	Experimental	1	1	1	0	1	0	1	1	1	1	1
	Control	0	0	1	1	0	0	1	1	0	0	1
2	Experimental	1	0	1	0	1	0	1	1	1	0	0
	Control	1	0	0	0	0	0	0	0	1	0	1
3	Experimental	1	0	1	0	1	0	1	1	1	1	1
	Control	1	1	1	0	1	0	1	1	1	1	0
4	Experimental	1	1	1	0	1	0	1	1	1	1	0
	Control	1	0	1	0	1	0	1	1	1	1	0
5	Experimental	1	1	1	1	1	1	1	1	1	1	1
	Control	1	0	0	0	0	0	1	0	1	1	0
6	Experimental	1	1	1	1	1	0	1	1	1	1	1
	Control	1	0	1	0	1	0	0	0	1	1	1
7	Experimental	1	0	1	0	1	0	0	0	1	1	0
	Control	1	0	1	1	0	0	0	0	0	0	1
8	Experimental	1	1	0	0	1	0	1	0	1	0	1
	Control	1	0	1	0	0	0	1	1	1	1	0
9	Experimental	1	1	1	1	1	1	1	1	1	1	1
	Control	0	0	1	0	0	0	1	1	1	0	1
10	Experimental	1	0	1	0	1	0	1	1	1	1	1
	Control	0	0	0	0	0	0	1	1	1	0	0
11	Experimental	1	0	1	0	1	1	1	1	1	1	1
	Control	1	0	1	0	1	0	0	0	1	1	1
12	Experimental	1	1	1	1	1	0	1	1	1	1	1
	Control	1	0	1	0	1	0	1	0	1	0	0
13	Experimental	1	0	1	0	1	0	1	1	1	1	1
	Control	0	0	0	1	1	0	0	0	0	1	0

TABLE 17--(Continued)

Pair	Student	1-0	2-0	3-0	4-0	5-0	6-0	7-C	8-C	9-C	10-C	11-M
14	Experimental	1	0	1	0	1	0	0	0	1	0	1
	Control	0	0	0	1	1	0	1	0	1	1	1
15	Experimental	1	1	1	0	1	0	1	1	1	0	1
	Control	1	0	1	1	1	0	0	0	1	1	1
16	Experimental	1	1	1	0	1	0	1	1	1	0	1
	Control	1	1	1	1	1	0	0	1	1	0	1
17	Experimental	1	0	0	0	1	0	1	1	1	0	0
	Control	0	0	0	0	0	0	0	0	1	1	1
18	Experimental	1	0	1	0	1	0	0	0	1	1	0
	Control	1	0	0	0	1	0	0	0	1	1	1
19	Experimental	1	1	1	0	1	0	1	1	1	1	1
	Control	1	0	1	0	1	0	1	1	1	1	1
20	Experimental	1	0	1	0	1	0	1	1	1	1	1
	Control	1	0	0	0	0	0	1	1	0	0	1
21	Experimental	1	0	0	0	1	0	1	0	1	1	1
	Control	1	0	1	0	1	0	1	1	1	0	1
22	Experimental	1	1	1	0	1	0	1	1	1	1	1
	Control	0	0	1	0	0	0	1	1	1	1	1
23	Experimental	1	0	1	0	1	0	1	1	1	1	1
	Control	1	1	1	0	1	0	0	0	0	0	1
24	Experimental	1	0	1	0	1	1	1	1	1	1	1
	Control	0	0	1	0	0	0	1	0	1	1	0
25	Experimental	1	1	1	0	1	0	1	1	1	0	1
	Control	0	0	1	0	0	0	1	1	1	1	0
26	Experimental	1	1	1	0	1	0	1	1	1	1	1
	Control	1	0	1	0	0	0	0	0	1	1	1
27	Experimental	1	1	1	0	1	0	1	1	1	1	1
	Control	0	0	0	0	0	0	0	0	1	1	0
28	Experimental	1	1	1	0	1	0	1	1	1	1	1
	Control	0	0	1	0	0	0	0	0	1	1	1
29	Experimental	1	1	1	0	1	0	1	1	1	1	1
	Control	0	0	1	0	1	0	0	0	1	1	1
30	Experimental	1	1	1	1	1	0	1	1	1	0	1
	Control	1	0	1	0	1	0	0	0	0	1	0

TABLE 17--(Continued)

Pair	Student	12-M	13-M	14-M	15-M	16-M	17-E	18-E	19-E	20-E	21-E	22-E	23-I
1	Experimental	1	1	1	1	1	1	1	1	1	1	1	1
	Control	1	1	0	0	0	0	0	0	0	1	0	1
2	Experimental	0	0	0	0	0	1	0	1	0	1	0	1
	Control	0	0	0	0	0	0	0	0	0	0	0	1
3	Experimental	1	0	0	1	1	1	1	1	1	0	0	1
	Control	0	0	0	0	0	0	0	0	0	0	0	1
4	Experimental	0	0	0	0	1	1	1	1	0	1	0	1
	Control	0	0	0	0	1	0	0	0	0	0	0	1
5	Experimental	1	1	1	0	1	1	1	1	1	1	0	1
	Control	0	0	0	0	0	1	1	0	0	1	0	1
6	Experimental	1	0	0	1	1	1	1	1	1	1	1	1
	Control	1	0	0	0	0	0	0	0	0	0	0	1
7	Experimental	0	0	0	0	0	0	0	1	1	1	0	1
	Control	1	0	0	1	0	1	1	0	0	0	0	1
8	Experimental	1	0	0	0	1	1	1	1	1	1	0	1
	Control	0	1	0	1	0	1	1	0	0	1	1	1
9	Experimental	0	1	1	0	0	1	1	0	0	1	1	1
	Control	1	0	0	0	0	1	1	0	0	1	0	1
10	Experimental	1	0	0	1	1	1	1	0	0	1	0	1
	Control	0	0	0	0	0	1	1	0	0	0	0	1
11	Experimental	1	1	0	1	1	1	1	1	0	1	1	1
	Control	0	0	0	0	0	0	0	0	0	0	0	1
12	Experimental	1	1	1	1	1	1	1	1	1	1	1	1
	Control	0	1	1	0	0	1	1	0	0	1	0	1
13	Experimental	1	1	1	1	1	1	1	0	0	1	0	1
	Control	0	0	0	0	0	1	1	0	0	0	0	1
14	Experimental	1	0	0	0	0	1	1	1	1	0	0	1
	Control	0	0	0	0	1	1	1	0	0	0	0	1
15	Experimental	1	0	0	1	1	1	1	1	1	1	0	1
	Control	0	0	0	0	1	1	1	0	0	0	0	1
16	Experimental	1	1	1	1	1	0	0	0	0	0	0	1
	Control	0	0	1	1	1	0	0	0	0	1	0	1

TABLE 17---(Continued)

Pair	Student	12-M	13-M	14-M	15-M	16-M	17-E	18-E	19-E	20-E	21-E	22-E	23-I
17	Experimental	0	0	0	1	1	1	1	1	0	0	0	1
	Control	1	1	0	0	1	1	1	0	0	0	0	1
18	Experimental	0	0	0	0	0	1	1	1	1	0	0	1
	Control	1	0	0	0	0	0	0	1	0	0	0	1
19	Experimental	1	1	0	0	1	1	1	1	1	1	0	1
	Control	0	0	0	[illegible]	0	1	0	0	0	0	0	1
20	Experimental	0	0	0	0	0	1	1	0	0	1	1	0
	Control	0	0	0	1	1	0	0	0	0	0	0	1
21	Experimental	1	0	0	0	0	1	1	0	0	1	1	0
	Control	1	0	0	0	0	1	1	0	0	0	1	1
22	Experimental	1	1	1	0	1	0	0	1	1	1	0	1
	Control	1	0	0	0	1	1	1	0	0	0	0	1
23	Experimental	1	1	1	0	0	1	1	1	1	1	0	1
	Control	1	0	0	0	0	1	1	0	0	1	0	1
24	Experimental	1	1	1	1	1	1	1	1	1	1	0	1
	Control	0	0	0	0	1	0	0	0	0	1	0	1
25	Experimental	1	1	0	0	0	1	1	1	0	0	0	1
	Control	0	0	0	0	0	1	1	1	1	0	0	1
26	Experimental	1	0	0	0	1	1	1	0	0	1	0	1
	Control	1	0	0	1	1	0	0	1	0	0	0	1
27	Experimental	1	0	0	1	1	1	1	1	0	1	0	1
	Control	0	0	0	0	0	1	1	0	0	0	0	1
28	Experimental	1	1	0	0	0	1	1	1	1	1	0	1
	Control	0	0	0	0	0	1	1	0	0	0	0	1
29	Experimental	1	0	0	1	0	1	1	1	1	1	1	1
	Control	1	0	0	0	0	1	1	0	0	0	0	1
30	Experimental	1	0	0	1	0	1	1	1	1	0	0	1
	Control	0	0	0	0	1	1	1	1	1	0	0	1

TABLE 17--(Continued)

Pair	Student	24-I	25-K	26-I	27-I	28-I	29-P	30-P	31-P	32-P	33-P	34-P
1	Experimental	1	1	1	1	1	1	1	1	1	1	1
	Control	1	0	1	1	1	1	1	1	1	1	0
2	Experimental	1	0	0	1	0	0	0	0	0	1	0
	Control	1	1	0	0	0	0	0	0	0	0	0
3	Experimental	1	0	0	0	0	1	1	1	1	1	1
	Control	1	0	1	1	0	0	0	0	1	0	0
4	Experimental	1	0	0	1	0	1	1	1	1	1	0
	Control	1	0	0	0	0	0	0	1	1	1	1
5	Experimental	1	0	0	1	1	1	1	1	1	1	0
	Control	1	1	0	1	0	0	0	1	1	0	0
6	Experimental	1	0	0	0	0	1	1	1	1	1	0
	Control	0	0	1	1	0	1	1	0	0	0	0
7	Experimental	1	0	0	0	0	0	0	0	0	0	0
	Control	1	0	0	0	0	1	1	0	0	0	0
8	Experimental	1	1	0	1	1	1	1	1	1	1	1
	Control	1	1	1	1	0	1	1	1	1	0	0
9	Experimental	1	0	0	1	1	1	1	1	1	1	1
	Control	1	1	1	1	1	1	0	1	1	1	0
10	Experimental	1	0	0	1	1	0	0	1	1	1	0
	Control	1	0	0	0	0	1	1	1	1	0	0
11	Experimental	1	0	0	1	1	1	1	1	1	1	0
	Control	1	0	0	1	0	0	0	0	0	0	0
12	Experimental	1	0	0	1	1	1	1	1	1	1	0
	Control	1	0	0	1	1	1	1	0	0	0	0
13	Experimental	1	1	1	1	0	1	1	1	1	1	0
	Control	1	0	0	0	0	0	0	0	0	0	0
14	Experimental	1	1	1	1	0	0	0	1	1	1	1
	Control	1	0	0	0	0	0	0	1	1	0	0
15	Experimental	1	0	0	1	0	0	0	1	1	0	0
	Control	1	1	0	1	0	0	0	1	1	1	1
16	Experimental	1	0	0	1	1	1	1	1	1	1	1
	Control	1	0	0	1	1	0	0	1	1	1	1

TABLE 17--(Continued)

Pair	Student	24-I	25-I	26-I	27-I	28-I	29-P	30-P	31-P	32-P	33-P	34-P
17	Experimental	1	0	0	1	0	1	1	1	1	1	1
	Control	1	0	0	0	0	0	0	0	0	0	0
18	Experimental	1	1	1	1	1	1	1	[illegible]	1	1	0
	Control	1	0	0	1	0	0	0	0	0	1	0
19	Experimental	1	1	1	1	0	1	1	1	0	1	0
	Control	1	0	0	0	0	0	0	0	0	1	0
20	Experimental	0	0	0	1	0	1	1	1	1	1	0
	Control	1	0	0	0	0	1	1	0	0	1	0
21	Experimental	0	1	0	1	0	1	0	0	0	1	0
	Control	0	0	0	0	0	1	1	1	1	1	0
22	Experimental	1	1	0	1	1	1	1	1	1	0	0
	Control	1	1	0	1	1	1	1	1	1	1	0
23	Experimental	1	1	1	1	1	1	1	1	1	1	0
	Control	1	0	0	1	1	0	0	0	0	1	1
24	Experimental	1	0	0	1	0	1	1	0	0	1	0
	Control	1	0	0	1	1	1	1	1	1	1	0
25	Experimental	1	0	0	0	0	1	1	1	1	1	0
	Control	1	1	0	1	1	0	0	0	0	0	0
26	Experimental	1	0	0	1	1	1	1	1	1	1	0
	Control	1	0	0	1	1	0	0	1	1	1	0
27	Experimental	1	0	0	1	0	1	1	0	0	0	0
	Control	1	1	0	0	0	1	1	1	1	1	1
28	Experimental	1	0	0	1	1	1	1	1	1	1	1
	Control	1	0	0	0	0	0	0	1	1	0	0
29	Experimental	1	1	0	1	1	1	1	1	1	1	1
	Control	1	0	0	0	0	0	0	1	1	1	1
30	Experimental	1	1	0	1	0	1	0	0	1	1	0
	Control	1	1	0	0	0	1	1	0	0	0	0