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THE RELATIONSHIP BETWEEN AN INQUIRY TEACHING APPROACH

AND INTELLECTUAL DEVELOPMENT

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TABLE OF CONTENTS

LIST OF TABLES AND GRAPHS

CHAPTER I

INTRODUCTION

Background of the Problem

Recent curriculum developments in junior high school science have abandoned traditional methods, which were largely lecture-demonstration, as well as traditional objectives. The new objectives, rather than placing primary import on the acquisition of factual information, are directed toward effecting a behavioral change in the individuals involved--namely, the development of the ability to solve problems in a logical manner.

How can this be evaluated? Consider this statement from the Teacher's Guide for the Introductory Physical Science course, "Achievement in this course manifests itself in several ways, some of which are not accessible to quantitative measurement."[1] Two of these are such intangibles as " . . . the improvement shown in the students' skill in communicating orally the results of their laboratory work or the reasoning

[1]I. P. S. Group, Educational Services Incorporated. Teacher's Guide, Introductory Physical Science, Prentice-Hall, Inc., 1967, p. ix.

behind the solution of a problem."[2] If we are to make meaningful statements about the value of the new courses, such as Introductory Physical Science (I.P.S.), Time, Space, and Matter (T.S.M.), and the Earth Science Curriculum Project (E.S.C.P.), ways must be found to evaluate changes in reasoning ability.

Piaget and Inhelder [3] (in the book The Growth of Logical Thinking) suggest certain tasks[4] that the learner can perform which identify his position in an intellectual developmental hierarchy; those tasks identify changes in reasoning ability as the learner moves through several stages in the hierarchy.

Piaget's approach to identifying different aspects of the child's intellectual development has been systematic and empirical through the use of well defined experimental type questions to large numbers of subjects. A preliminary survey made in the spring of 1969 at Central and University Junior High Schools in Norman, Oklahoma showed that 65 out of the 75 students tested did not achieve Piaget's criteria for formal logic, i.e., reach the stage of formal operations, in all areas.

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[2]Ibid., p. x.

[3]Jean Piaget and Barbel Inhelder, Growth of Logial Thinking, Basic Books, Inc., 1958.

[4]The tasks are explained in Appendix A.

The Piagetian stages of intellectual development differ in the way information is received and processed. These stages are: Sensory-motor (0-2 years), preoperational (2-7 years), concrete operational (7-11 years) and formal operational (11+ years). The age at which a learner moves from stage to stage, or deeper into a stage, is flexible. Piaget states that "To divide developmental continuity into stages recognizable by some set of external criteria is not the most profitable of occupations."[5]

The concrete learner is characterized by his ability to follow properties of objects through transformations and to operate on concrete objects, i.e., he can mentally carry out a series of related actions on objects with which he had had experience. This permits the concrete learner to develop and deal effectively with concepts gained from his experiences with objects, and to mentally solve problems by reasoning from his experiences with objects.

To distinguish the concrete and formal operational stages is to describe the differences in the performance of the learners upon propositions. No longer does the learner need a hierarchy of concepts nor concrete objects from which to form logical operations. The formal learner is mentally capable of doing interpropositional operations; " . . . he is concerned with reality, but reality is only a subset within

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[5]Jean Piaget, The Psychology of Intelligence (New York: Harcourt, Brace, 1950), p. 139.

a much larger set of possibilities."[6]

"An operation is a reversible internalizable action which is bound up with others in an integrated structure,"[7] thus a mental structure is a group of logically related operations. Formal operational thought depends upon the integration of separate structures into a "structured whole."[8]

Piaget links the development of formal structures in adolescence to the development of the body as a whole as well as the development of the nervous system and mental functions, the demands of the culture and interaction with the physical environment.[9]

Piaget states that the logical thought processes change most significantly when a learner is permitted to interact with objects, events and situations in his environment. One of the primary differences in the curricula studied by the experimental and control groups in this research was that those in the experimental groups interacted with materials which, in turn, led them to develop the understanding of the concept being considered. In other words, the curricula studied by the experimental groups should, according to Piaget, encourage them to develop logical thought processes more fully than those

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[6]John L. Phillips, Jr., The Origins of Intellect; Piaget's Theory (San Francisco: W. H. Freeman and Co., 1969), p. 101.

[7]Piaget and Inhelder, *op. cit.*, p. xiv.

[8]*Ibid.*

[9]Jean Piaget, "Development and Learning," Journal of Research in Science Teaching, Vol. 2, #3, 1964, pp. 176-186.

in the control group who did not have the opportunity to interact with materials in the same manner the experimental group did.

The Piagetian tasks were used as evaluative criteria to determine if an inquiry-centered curriculum as opposed to the traditional-centered curriculum supplied the student with the intellectual development necessary to allow him to enter into the stage of formal thinking.

Since junior high school students are between the ages of 13 and 15 years, they can be expected to be progressing into the stage of formal operations. They should, therefore, be able to perform the Piagetian tasks; according to Piaget they are sufficiently mature, and our complex modern culture seems to place a premium on the ability to use logical thought processes. The science curricula chosen for this study will provide the necessary interaction with the physical environment.

Statement of the Problem

The problem of this investigation was to determine whether junior high school students exposed to science courses which allow them to interact with their physical environment through inquiry show more progress in moving toward the attainment of formal operations than do students with similar maturation levels and cultural exposures enrolled in a traditional, lecture-demonstration type science class.

When an individual reacts with his physical environment he performs activities which have been described by the Educational Policies Commission in their definition of the ability to think:

> . . . the processes of recalling and imagining, classifying and generalizing, comparing and evaluating, analyzing and synthesizing, and deducing and inferring.[10]

These processes are embodied in the science courses used in this study, I.P.S., E.S.C.P., and T.S.M.

The hypothesis tested was that students who are exposed to an inquiry-type science course showed no significant gains in their ability to think logically when compared with students taking a traditional, lecture-demonstration type course. The students who participated in the experiment were drawn from the junior high school populations of Norman and Oklahoma City.

Related Research

There is no research available for review which deals with the relationship between educational experiences and operational level in the junior high school. The proposed research suggested itself when a recent study done at the University of Oklahoma focused attention on a child's rate of logical development. The hypothesis is made by many that entering into a particular stage of logical development cannot be

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[10]Educational Policies Commission, The Central Purpose of American Education (Washington, D. C.: National Education Association, 1961), p. 12.

accelerated. During the 1968-69 academic year, Renner and Stafford[11] tested that hypothesis with first grade learners. Renner and Stafford determined the operational level of 120 first grade children in September, 1968, and 60 of them were provided experiences with a science program as represented by the standard textbooks in elementary school science, and the remaining 60 were provided the experiences designed and tested by the Science Curriculum Improvement Study (S.C.I.S.). The results from the research are shown in Tables 1 and 2.[12] Those results clearly show that those children who had the first grade science program of S.C.I.S. entered into the concrete operational stage (as represented by the number of conservations they accomplished) more than did the group which had studied a conventional science program. These results have led to the tentative hypothesis that certain curricular experiences which are educationally defensible as proper for junior high school students can also affect the rate at which a learner enters into a given operational stage. This seems, on the basis of the data available, a reasonable and testable hypothesis.

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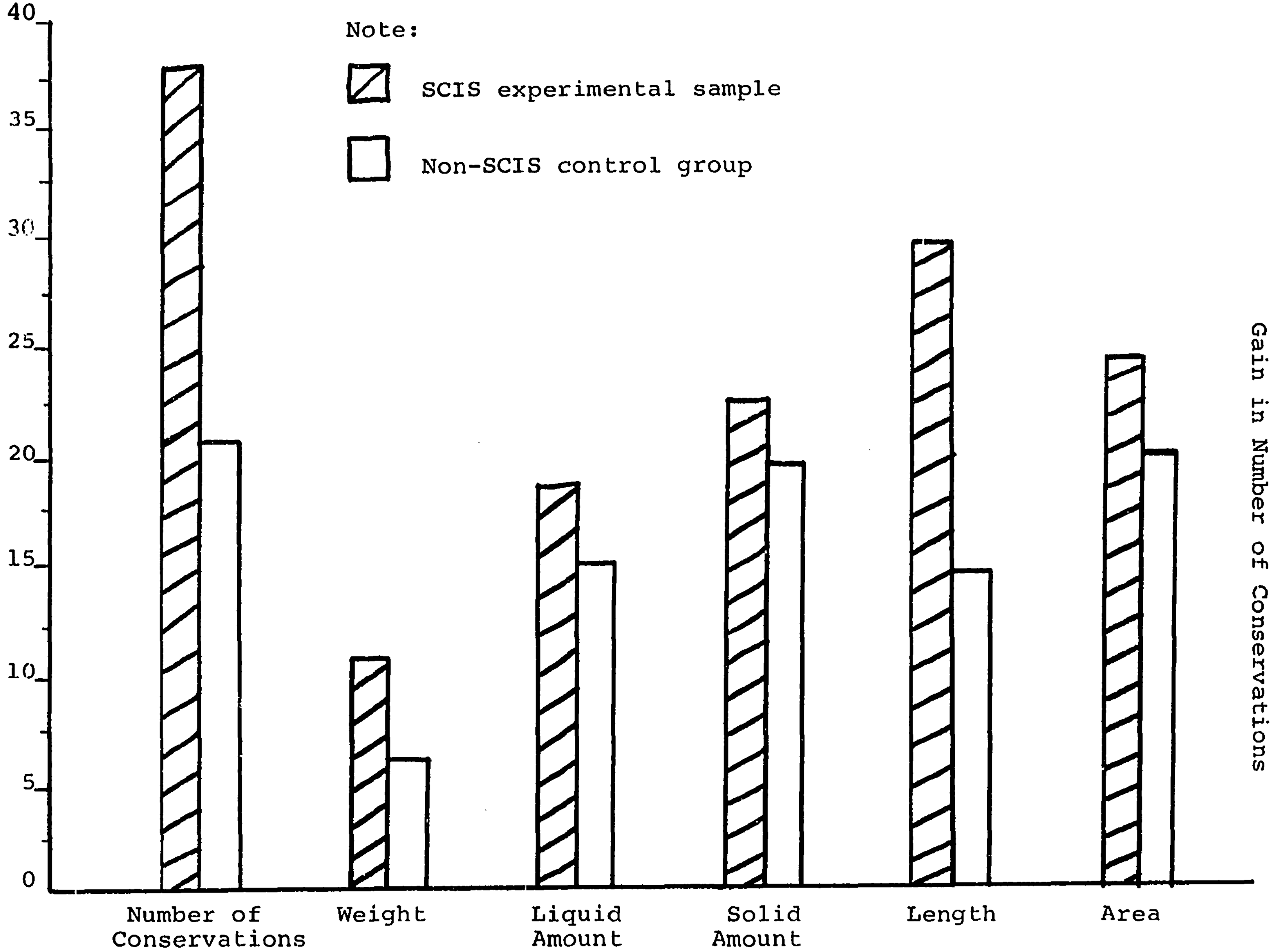
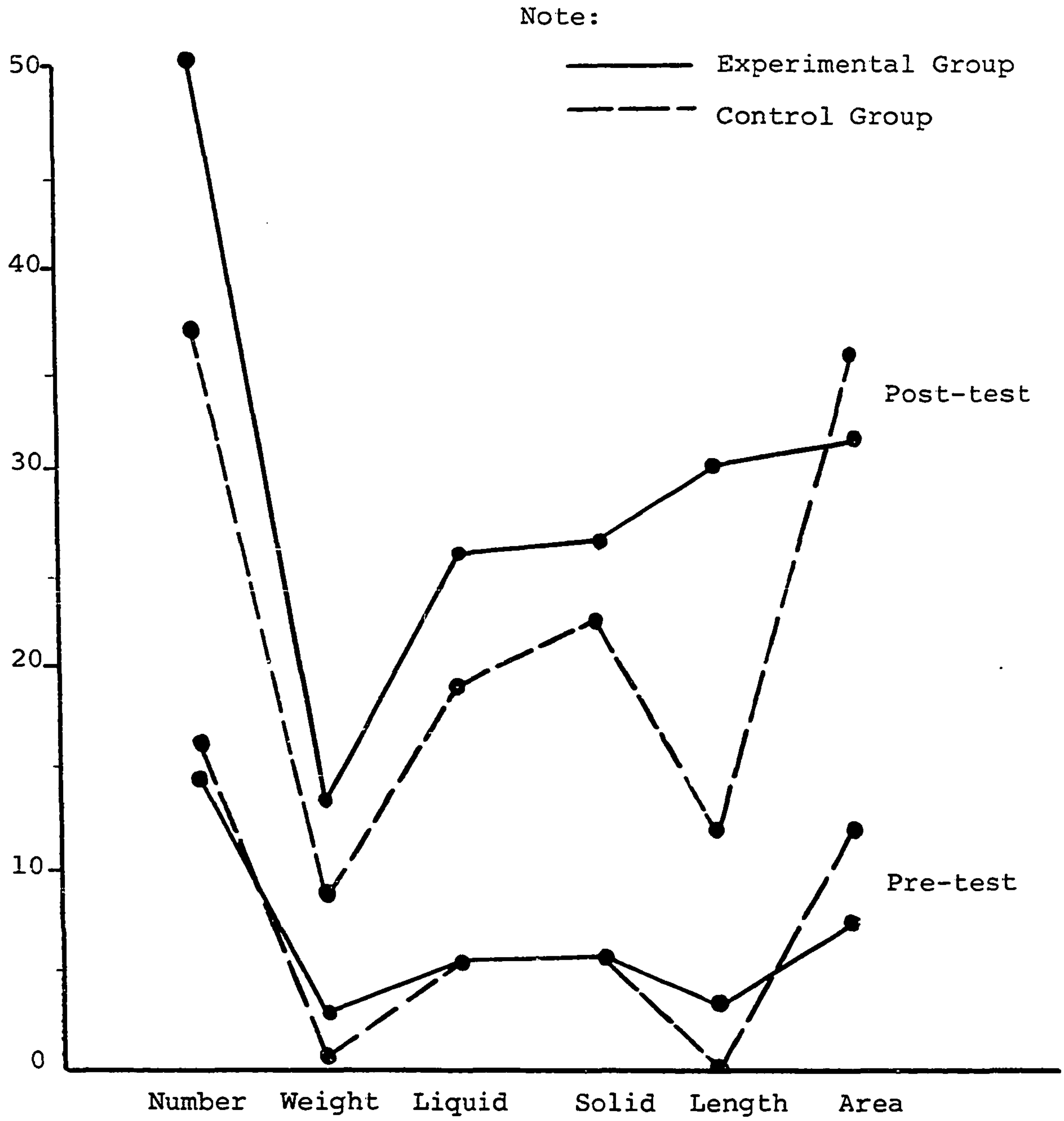
[11]John W. Renner and Donald G. Stafford, "Inquiry, Children and Teachers," The Science Teacher, Vol. 37, #4 April, 1970, pp. 55-57.

[12]Donald G. Stafford, The Influence of the First Grade Program of the Science Curriculum Improvement Study on the Rate of Attainment of Conservation, University of Oklahoma, Ph. D., 1969.



GRAPH 1

CONSERVATION FACTORS
INCREASE IN CONSERVATIONS



GRAPH 2

CONSERVATION FACTORS
TOTAL CONSERVATIONS FOR EACH SAMPLE BY TASK

Joe W. McKinnon, working with students at Oklahoma City University, tested a similar hypothesis. He used freshman students enrolled in a newly developed course entitled "Forum for Scientific Inquiry" which used inquiry techniques and freshman students not enrolled in science classes. The students were evaluated according to the acquisition of the ability to perform formal operational tasks. He found that there was a significant difference in the acquisition of formal operational thought patterns by the two groups.[13] Piaget states his views on the acceleration of formal operations as follows:

> The age of 11-12 years, which in our society we found to mark the beginning of formal thinking, must be extremely relative, since the logic of the so-called primitive societies appears to be without such structures. Moreover, the history of formal structures is linked to the evolution of culture and collective representations as well as their ontogenetic history. Since Greek adults became aware of some of these structures only in their logical and mathematical reflection, it is probable that Greek children are behind our own. Thus, the age of 11-12 years may be, beyond the neurological factors, a product of a progressive acceleration of individual development <u>under the influence of education</u>, and perhaps nothing stands in the way of a further reduction of the average age in a more or less distant future.[14]

The researcher, after a thorough search of the literature, believes that the type of project herein outlined has not been attempted elsewhere. The results are valuable both

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[13]Joe W. McKinnon, <u>The Influence of a College Inquiry Centered Course in Science on Student Entry into the Formal Operational Stage</u>, University of Oklahoma, Ph.D., 1970.

[14]Piaget and Inhelder, <u>op</u>. <u>cit</u>., p. 328. (underlining for emphasis by the investigator).

for the general information they give regarding the acquisition of formal operations and for the specific information about which of the curricula used best suited the purpose of enhancing the attainment of formal operations.

Origin of the Problem

The investigator became aware of the problem of a seeming lack in mental abilities when she attempted to teach the concept of density to eighth grade students. The students were to derive this concept from investigating the masses and volumes of various substances; most were unable to derive the concept. Many did not have the ability to use the concept of mass meaningfully--they would equate it to weight or volume. In addition, many could not fully grasp the concept of volume. Some of the learners would eventually memorize that determining the volume of an object involves using three dimensions and that this is expressed in cubic units. However, when questioned about the process of volume determination they revealed that they were filling in blanks in a useful formula; when the problem was presented in a new way, they could not solve it. Piaget states that this concept is conserved and therefore understood only at the beginning of formal operations. Because of these factors, the integration of mass and volume to form a concept of density is a formidable task indeed!

But, learners in most junior and senior high school earth and physical science programs must use this concept; some courses are constructed with density as a pervasive theme, the understanding of which is necessary for a successful experience in the course.

Because of the difficulty that the learners have with curricula recommended for use in the eighth and ninth grades, the investigator wishes to establish the operational level of eighth and ninth graders and to investigate the possibility of advancing the operational level through the use of inquiry-type science curricula.

Working Hypotheses

The basic working hypotheses are:

1. At least 75 per cent of eighth and ninth graders, ages 13 to 15, are concrete operational.

2. Students who are concrete operational or have just entered the formal operational stage will move into formal operations or more deeply into that stage because of their experiences in an inquiry-type science program.

Statistical Hypotheses

The above problems, stated in null form are:

1. All junior high school students perform selected tasks at a level designated by Piaget as being formal operational.

2. Students who are not fully formal operational and who are exposed to an inquiry-type science curriculum will show no significantly greater growth in acquisition of formal operations than students enrolled in a traditional science course.

The second hypothesis was tested at the 0.10 level. The researcher's main goal was not to accept the null hypothesis if it is actually false. To do so would impede the further development and implementation of inquiry-type science courses. As was stated before, some of the achievements of inquiry-type courses are not readily evaluated on a numerical basis. It would indeed be a tragedy to label these courses as ineffective because the tests used could not adequately evaluate the achievement of the students.

The reverse, rejecting the null hypothesis when it was actually true, would do far less harm. This decision is made with the full realization that the treatment may be given too much emphasis.

The data were analyzed statistically and displayed graphically and in chart form. For the statistical treatment, the test results were evaluated with no points given for a pre-operational level answer, one point for a stage IIa and two points for a IIb in concrete operations, and three points for stage IIIa and four points for IIIb in formal operations.[15] This gives a numerical basis for evaluation of individuals as well as groups.

Significance of the Study

The study provides an evaluation of available science curricula on the basis of providing activities which lead

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[15]The designations IIa, IIb, IIIa, and IIIb are explained in Appendix A.

eighth and ninth graders into the formal operational stage, i.e., being able to use logical thought processes. The results of the study, therefore, are valuable to school systems, state departments of education, teacher preparation institutions, and curriculum researchers. Such information is also of assistance to school systems and state departments of education as they prepare new courses-of-study and recommend materials.[16]

Teacher preparation institutions can make use of these findings to aid students in their study and evaluation of available materials and the proper grade placement of subject matter. The data are also of value in the study of cognitive development and learning characteristics and abilities of junior high school students. Curriculum specialists can use the findings as a basis for further construction and evaluation of materials for the junior high school learner.

This information can be disseminated by publishing reports of the findings in scholarly journals, newsletters supported by the curriculum projects (e.g., E.S.C.P. Newsletter) and direct mailing to state departments of education and teacher preparation institutions.

Following this study, a detailed examination of the science curricula used should be made to ascertain the particular elements of each course-of-study which help develop the

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[16]The Improvement of Science Instruction in Oklahoma Grade 7 through 12, Oklahoma State Department of Education, 1970.

cognitive structure of the learner. These segments should be analyzed in an attempt to determine how these cognitive structures can be augmented.

CHAPTER II

SELECTION OF THE SAMPLE AND ADMINISTRATION OF THE FORMAL OPERATIONAL TASKS

The population from which the subjects for the proposed research was drawn was the eighth and ninth grade students at Central and West Junior High Schools in Norman, and eighth grade students at University Junior High School, Norman, and Harding Junior High School, Oklahoma City.

There were seven classes involved in the research, which were distributed among the experimental groups (those studying T.S.M., I.P.S., and E.S.C.P.) and the control groups (those studying general science) according to the scheme shown in Table 1. The total number of students involved was 210.

Table 1

Curriculum	No. of Students
Eighth Grade	
I.P.S.	30
E.S.C.P.	30
T.S.M.	30
Traditional	30
Ninth Grade	
I.P.S.	30
E.S.C.P.	30
Traditional	30

Each student had certain required subjects and certain elective subjects in which he enrolled. There is, however, no reason to believe that any combination of subjects presently existing at the institutions moves a student into formal logic any better than any other combination of subjects. In other words, the only factor which will be different in the educational experiences of the control group and the experimental group is the inquiry experience in science which the experimental group will have. Required subjects are English, social science, mathematics, and science.

Since most eighth and ninth graders are between 13 and 15 years of age, they are well within that portion of the intellectual development spectrum during which Piaget declares that formal operations should be present. Each student in the study, therefore, must react to those tasks which Piaget has developed to isolate a formal thinking individual at the beginning of the research. The data collected from administering the formal operational tasks enable the researchers to place students into the categories of concrete operational, formal operational or in a transitional state. Administration of the pre- and post-tests allowed determination of the progress of individual learners to be made. The first data gathering process was completed in September, 1969. Each student responded to five tasks which Piaget declares are indicative of a learner moving into the formal operational stage of development, and one task, the conservation of solid amount, that is on the concrete operational level. The students were tested for the ability to perform the tasks listed in Appendix A.

Each child was evaluated on these tasks again in April or May, 1970. <u>All data available lead to the conclusion that a learner will not respond correctly to the tasks (with the exception of the conservation of weight) until he is formal operational</u>. <u>The repeated use of the tasks, therefore, does not lead to spurious results</u>. There cannot be, however, any attempt on the part of the teachers in either the experimental or control groups to specifically teach the six tasks or certain concrete operational children would attempt to memorize the answers. In order to eliminate the temptation of teaching the solution to the tasks, the teachers did not view or participate in the testing.

For each subject in the research, there are two measures of each of six tasks or twelve separate discrete pieces of data. The size of the data collection is emphasized to show the impact that student communications about the tasks would have on the study's results. In order to have an effect, that communication would need to be quite thorough and refined to distort the picture provided by 2520 bits of data. In addition, the tests are spaced chronologically quite far apart. In order for one student telling another to distort the picture provided by the data, many students who are not formal operational, would have to remember for long periods of time information which it is not within their ability to assimilate. The probability of distortion due to student communication seems low.

Description of Courses Used

Those students in the experimental groups will study the work of three separate national curriculum groups as explained in Table 1. The E.S.C.P. course selects its content for investigation from those fields of science concerned with studying the earth and its atmospheric environment. While the learners perform many investigations, the course is somewhat more content-oriented than the other experimental curricula used in this project. The I.P.S. curriculum is oriented toward the overall goal of developing understanding, through investigation, of the structure of matter. The student materials consist of instructions for performing investigations, many questions, and very few answers! The T.S.M. course is a study of the matter found on the earth and elsewhere in our solar system and the time-space relationship of this matter. The printed material for the students is minimal, consisting of nine picture folios and a series of reading phamphlets. The student literally writes his own book as he keeps the daily record of his observations and investigations.

Teachers of the Experimental Groups

The experimental groups in this study are taught by six different teachers, each one handling a different curriculum. They are experienced teachers, selected by their administrators, the researcher and her advisor as being competent to teach the courses assigned to them. Those making the selection were acquainted with both the individuals involved and the curricula being used. Each teacher involved in one of the inquiry-type curricula had received special education in the use of that type of curriculum.

Having six teachers involved introduces variables that would not be present if all groups were taught by the same instructor. This would be an impossible task, however, because of the different curricula and numbers of students involved in the study. Furthermore, an individual who had been educated to teach one of the inquiry-type curricula would carry this philosophy and methodology over into his treatment of a traditional course; it would be difficult for a teacher to handle more than one curriculum and not be biased in his treatment of one of the courses.

Record of the Test

A record was kept by the tester for each learner during the pre-test and the post-test. There were blanks provided for each of the tests used so that the level of the response could be recorded. Separate data sheets were used for the pre- and post-testing so that the tester would not be aware, at the time of the post-test, of the responses made on the pre-test. In addition to responses to the solution of the six Piagetian tasks, each learner was asked his name and date of birth. Samples of the data sheets used are in Appendix C. The researcher also obtained I.Q. scores from the guidance departments of the cooperating schools.

The information from the two data gathering sessions and the guidance departments is given in the data section (Chapter III), and was used in the analysis of data section (Chapter IV). The subjects are designated by numbers because of the confidential nature of sections of the data. An explanation of the statistical methods used is found in Appendix D.

Hypotheses Tested

The following hypotheses were tested using Analysis of Covariance techniques:

1. There is no significant difference in the rate of attainment of formal operations by eighth-grade pupils who take a course using Time, Space and Matter materials and those who take general science.

2. There is no significant difference in the rate of attainment of formal operations by eighth-grade pupils who take a science course using Earth Science Curriculum Project materials and those who take general science.

3. There is no significant difference in the rate of attainment of formal operations by eighth grade pupils who take a course using Introductory Physical Science materials and those who take general science.

4. There is no significant difference in the rate of attainment of formal operations by eighth-grade pupils who take a science course using <u>Introductory Physical Science</u> materials and those who take a science course using <u>Time, Space and Matter</u> materials.

5. There is no difference in the rate of attainment of formal operations by eighth-grade pupils who take a science course using Earth Science Curriculum Project materials and those who take a course using <u>Introductory Physical Science</u> materials.

6. There is no significant difference in the rate of attainment of formal operations by eighth-grade pupils who take a science course using Earth Science Curriculum Project materials and those who take a science course using <u>Time, Space and Matter</u> materials.

7. There is no significant difference in the rate of attainment of formal operations by ninth-grade pupils who take a science course using <u>Introductory Physical Science</u> materials and those who take general science.

8. There is no significant difference in the rate of attainment of formal operations by ninth-grade pupils who take a science course using Earth Science Curriculum Project materials and those who take general science.

9. There is no significant difference in the rate of attainment of formal operations by ninth-grade pupils who take a science course using Earth Science Curriculum Project

materials and those who take a science course using <u>Introductory Physical Science</u> materials.

10. There is no significant difference in the rate of attainment of formal operations by eighth-grade pupils who take a science course using <u>Introductory Physical Science</u> materials and ninth-grade pupils who take a science course using <u>Introductory Physical Science</u> materials.

11. There is no significant difference in the rate of attainment of formal operations by eighth-grade pupils who take a science course using Earth Science Curriculum Project materials and ninth-grade pupils who take a science course using Earth Science Curriculum Project materials.

12. There is no significant difference in the rate of attainment of formal operations by junior high school girls compared with junior high school boys.

The following hypothesis was tested using Pearson's formula for correlation, r:

There is no correlation between rate of attainment of formal operations and I.Q.

CHAPTER III

PRESENTATION AND DISCUSSION OF THE DATA

The data collected during this investigation were amassed for the purpose of ascertaining the operational level of junior high school learners and comparing the advancement of operational level of learners taking certain inquiry-centered curricula when compared with those who took traditional junior high school science courses. The data were also analyzed to give information about the relation of sex and I.Q. to attainment of formal operations.

The raw data are presented in Table 2 through Table 8. The symbols used to head each column are explained below:

C.A. = chronological age, in months

C.S. = cumulative score.

I = Piagetian pretest values.

II = Piagetian posttest values.

SA = the score on the Conservation of Solid Amount task.

V = the score on the Conservation of Volume task.

RI = the score on the Reciprocal Implication task.

EC = the score on the Elimination of Contradictions task.

SV = the score on the Separation of Variables task.

E = the score on the Exclusion task.

TABLE 2

EIGHTH GRADE GENERAL SCIENCE

Pupil No.	Sex	I.Q.	C.A.	C.S. I	I SA	I V	I RI	I EC	I SV	I E	C.S. II	II SA	II V	II RI	II EC	II SV	II E
1.	m	107	174	11	2	3	1	3	1	1	13	2	3	2	3	2	1
2.	f	120	172	9	2	1	2	1	1	2	11	2	3	2	2	1	1
3.	m	117	175	11	2	3	2	1	2	1	11	2	3	2	1	2	1
4.	f	108	168	8	1	3	1	1	1	1	11	1	3	2	3	1	1
5.	m	108	170	12	2	3	1	2	2	2	15	2	3	3	3	2	1
6.	m	126	174	15	2	3	2	3	3	2	15	2	3	3	1	3	3
7.	f	93	165	7	2	1	1	1	1	1	11	2	3	2	2	1	1
8.	m	106	167	12	2	3	1	1	2	3	14	2	3	2	2	2	3
9.	f	120	172	11	2	1	3	2	2	1	13	2	3	2	3	2	1
10.	m	118	169	9	2	3	1	1	1	1	17	2	3	3	3	3	3
11.	m	105	170	13	2	3	2	2	2	2	19	2	3	4	3	3	4
12.	m	106	171	9	2	3	1	1	1	1	11	2	3	2	1	2	1
13.	f	134	166	14	2	3	3	2	3	1	15	2	3	3	3	2	1
14.	m	97	180	12	2	3	2	2	2	1	12	2	3	2	3	1	1
15.	m	79	181	13	2	3	3	1	2	2	8	2	1	2	1	1	1
16.	f	87	181	7	2	1	1	1	1	1	11	2	3	2	2	1	1
17.	m	129	162	10	2	3	1	2	1	1	15	2	3	3	1	3	3
18.	m	106	178	13	2	3	3	2	2	1	12	2	1	4	3	1	1
19.	f	102	161	7	2	1	1	1	1	1	13	2	3	3	1	2	2
20.	m	106	169	12	2	3	1	1	2	3	15	2	3	2	3	2	3
21.	f	122	172	7	2	1	1	1	1	1	14	2	3	3	3	2	1
22.	f	84	170	10	1	3	1	1	2	2	10	2	3	2	1	1	1
23.	m	117	171	14	2	3	1	2	3	3	17	2	3	2	4	3	3
24.	f	103	169	7	2	1	1	1	1	1	8	2	1	2	1	1	1
25.	f	120	167	13	2	3	1	2	2	3	17	2	3	3	3	3	3
26.	f	104	73	10	2	1	1	1	2	3	8	2	1	1	2	1	1
27.	f	97	164	7	1	1	1	1	1	2	7	1	1	1	1	2	1
28.	f	106	169	8	2	1	1	1	2	1	8	2	1	2	1	1	1
29.	m	109	186	13	2	3	2	2	2	2	17	2	3	2	3	3	3
30.	m	108	172	8	2	1	1	1	2	1	14	2	3	3	3	2	1

TABLE 2

EIGHTH GRADE GENERAL SCIENCE

Pupil No.	Sex	I.Q.	C.A.	C.S. I	I SA	I V	I RI	I EC	I SV	I E	C.S. II	II SA	II V	II RI	II EC	II SV	II E
1.	m	117	172	14	2	3	2	2	2	3	17	2	3	3	3	3	3
2.	m	94	166	13	2	3	1	2	2	3	12	1	3	2	2	2	2
3.	f	130	169	8	1	3	1	1	1	1	8	2	1	2	1	1	1
4.	m	117	169	9	1	3	1	1	1	2	13	2	3	2	2	2	2
5.	f	100	174	6	1	1	1	1	1	1	14	1	3	2	1	3	3
6.	m	117	163	6	1	1	1	1	1	1	10	2	1	2	2	2	1
7.	m	133	177	7	1	1	1	2	1	1	10	1	3	2	1	2	1
8.	m	107	169	9	2	3	1	1	1	1	10	2	3	2	1	1	1
9.	f	117	163	9	2	3	1	1	1	1	12	2	3	2	2	2	1
10.	f	110	172	7	2	1	1	1	1	1	10	2	3	2	1	1	1
11.	m	126	164	15	2	1	3	3	3	3	18	2	3	4	3	3	3
12.	f	84	168	7	1	1	2	1	1	1	8	1	1	2	1	2	1
13.	m	98	172	12	2	3	1	2	2	2	9	1	3	2	1	1	1
14.	f	130	164	10	2	3	1	2	1	1	11	2	3	3	1	1	1
15.	m	120	166	7	2	1	1	1	1	1	10	2	3	2	1	1	1
16.	f	108	168	9	2	1	1	1	2	2	10	2	1	2	1	2	1
17.	f	135	167	13	2	3	3	1	2	2	13	2	3	3	1	2	2
18.	f	110	172	8	1	3	1	1	1	1	11	2	3	2	1	2	1
19.	m	110	169	11	2	3	1	1	2	2	12	1	3	2	1	3	2
20.	f	110	173	6	1	1	1	1	1	1	12	1	3	3	3	2	2
21.	m	110	163	8	1	3	1	1	1	1	10	2	3	2	1	1	1
22.	f	124	173	12	2	3	1	2	2	2	12	2	3	2	1	2	2
23.	f	130	171	6	1	1	1	1	1	1	10	1	3	2	1	1	2
24.	m	117	169	14	1	3	3	2	2	3	12	1	3	2	1	2	3
25.	f	135	161	8	1	3	1	1	1	1	9	1	3	2	1	1	1
26.	f	126	167	9	2	3	1	1	1	1	8	1	1	2	1	1	1
27.	m	108	172	11	2	3	1	1	2	2	6	1	1	1	1	1	1
28.	m	98	178	11	2	3	1	1	2	2	10	1	3	2	1	2	2
29.	f	128	169	10	2	3	1	1	1	2	14	2	3	3	1	2	3
30.	m	119	164	9	2	1	3	1	1	1	11	2	3	3	1	1	1

TABLE 4

EIGHTH GRADE INTRODUCTORY PHYSICAL SCIENCE

Pupil No.	Sex	I.Q.	C.A.	C.S. I	I SA	I V	I RI	I EC	I SV	I E	C.S. II	II SA	II V	II RI	II EC	II SV	II E
1.	f	87	179	8	2	3	1	1	1	1	7	1	1	1	1	2	1
2.	m	126	167	11	2	1	2	2	2	2	21	2	3	4	4	4	4
3.	f	123	163	11	2	3	1	1	2	1	16	2	3	4	2	4	1
4.	f	108	173	9	2	1	1	1	2	2	11	2	1	2	2	2	2
5.	m	120	171	10	1	3	1	1	2	1	12	2	3	1	2	2	2
6.	f	90	171	8	2	1	1	2	1	1	7	1	1	1	1	2	1
7.	f	108	173	6	1	1	1	1	1	1	9	1	1	1	1	2	3
8.	m	101	170	9	2	1	1	1	1	3	12	2	3	2	1	2	2
9.	m	126	166	10	2	3	1	1	1	2	13	2	3	2	1	2	3
10.	f	101	163	7	2	1	1	1	1	1	9	2	1	2	1	2	1
11.	m	124	170	12	2	3	2	2	1	2	14	2	3	3	2	2	2
12.	m	125	166	14	2	3	3	2	2	2	16	2	3	3	3	2	3
13.	f	96	164	7	2	1	1	1	1	1	7	1	1	2	1	1	1
14.	m	116	169	12	2	3	1	1	2	3	19	2	3	3	3	4	4
15.	m	83	166	9	2	3	1	1	1	1	12	2	1	3	1	1	3
16.	m	107	173	14	2	3	3	2	2	2	18	2	3	3	3	3	4
17.	f	120	169	7	2	1	1	1	1	1	12	2	3	1	1	2	3
18.	m	110	168	8	2	1	1	1	1	2	13	2	3	3	1	3	1
19.	m	113	167	11	2	1	1	3	1	3	16	2	3	3	3	2	3
20.	f	118	168	6	1	1	1	1	1	1	12	2	1	2	2	2	3
21.	f	123	164	9	2	1	1	1	2	2	11	2	3	1	1	1	3
22.	m	109	170	8	2	1	2	1	1	1	10	2	3	2	1	1	1
23.	m	136	170	17	2	3	3	3	3	3	18	2	3	4	4	3	2
24.	f	111	166	10	2	1	3	1	2	1	11	2	1	2	1	2	3
25.	f	113	165	7	2	1	1	1	1	1	10	1	3	2	1	2	1
26.	f	113	167	10	2	3	1	2	1	1	13	2	3	2	1	2	3
27.	m	110	168	10	2	3	2	1	1	1	14	2	3	3	1	3	2
28.	m	119	170	10	2	1	2	1	1	3	14	2	3	4	1	2	2
29.	f	73	183	7	2	1	1	1	1	1	9	2	1	2	1	1	2
30.	f	119	168	12	2	1	4	2	2	1	12	2	3	3	1	2	1

TABLE 5

EIGHTH GRADE TIME SPACE AND MATTER

Pupil No.	Sex	I.Q.	C.A.	C.S. I	I SA	I V	I RI	I EC	I SV	I E	C.S. II	II SA	II V	II RI	II EC	II SV	II E
1.	f	125	171	10	2	3	1	1	2	1	15	2	3	2	2	3	3
2.	m	124	173	10	2	3	1	1	2	1	16	2	3	3	2	3	3
3.	m	123	162	11	2	3	1	2	2	1	18	2	3	4	2	3	3
4.	f	123	174	14	2	3	2	2	2	3	15	2	3	2	2	3	3
5.	f	104	163	8	1	1	2	1	1	2	18	2	3	4	3	2	4
6.	m	122	163	9	2	3	1	1	1	1	17	2	3	4	3	2	3
7.	f	131	169	14	2	3	2	3	2	2	18	2	3	3	3	3	4
8.	m	135	163	13	2	3	2	2	2	2	17	2	3	3	3	3	3
9.	f	115	165	10	1	3	1	2	1	2	16	1	3	4	3	2	3
10.	m	126	162	11	2	3	3	1	1	1	16	2	3	4	3	2	2
11.	f	-	164	9	2	3	1	1	1	1	15	2	3	2	3	2	3
12.	f	126	163	11	2	3	2	1	2	1	19	2	3	4	3	4	3
13.	f	84	162	6	1	1	1	1	1	1	11	1	3	2	1	2	2
14.	f	124	167	13	2	3	2	1	2	3	16	1	3	3	2	3	4
15.	f	123	170	11	2	3	2	1	1	2	18	2	3	4	4	2	3
16.	m	105	172	9	2	1	1	1	2	2	17	1	3	4	3	3	3
17.	m	112	170	7	2	1	1	1	1	1	16	2	3	3	3	2	3
18.	m	105	166	10	1	3	3	1	1	1	16	1	3	4	3	2	3
19.	m	104	164	11	1	3	2	1	2	2	17	2	3	2	3	3	4
20.	m	126	164	14	2	3	2	2	3	2	19	2	3	3	4	3	4
21.	m	127	174	15	2	3	2	3	3	2	16	2	3	3	3	3	2
22.	m	92	184	6	1	1	1	1	1	1	12	2	3	2	1	2	2
23.	m	97	165	8	2	1	1	1	2	1	12	2	3	2	2	2	1
24.	f	109	168	8	1	1	2	1	1	2	15	2	3	3	2	2	3
25.	f	119	173	6	1	1	1	1	1	1	8	1	1	2	1	2	1
26.	m	123	167	8	2	1	1	1	1	2	12	2	3	2	2	2	1
27.	m	112	167	9	2	3	1	1	1	1	15	2	3	2	3	2	3
28.	m	111	162	8	2	1	1	1	2	1	19	2	3	4	3	3	4
29.	f	119	172	9	2	3	1	1	1	1	14	2	3	2	3	2	2
30.	m	121	166	15	1	2	4	3	3	1	19	1	3	4	4	4	3

TABLE 6

NINTH GRADE GENERAL SCIENCE

Pupil No.	Sex	I.Q.	C.A.	C.S. I	I SA	I V	I RI	I EC	I SV	I E	C.S. II	II SA	II V	II RI	II EC	II SV	II E
1.	f	105	185	8	1	3	1	1	1	1	9	1	3	2	1	1	1
2.	m	96	196	11	1	3	3	1	2	1	11	1	3	3	1	2	1
3.	f	113	181	8	2	1	1	1	1	2	11	2	3	2	2	1	1
4.	m	107	183	11	2	3	3	1	1	1	14	2	3	3	1	2	3
5.	f	116	177	10	2	3	1	1	1	2	14	2	3	2	1	3	3
6.	f	86	186	8	1	3	1	1	1	1	7	2	1	1	1	1	1
7.	m	113	181	9	1	3	1	2	1	1	15	2	3	2	3	2	3
8.	m	118	177	8	1	3	1	1	1	1	7	1	1	2	1	1	1
9.	f	98	176	6	1	1	1	1	1	1	8	1	3	1	1	1	1
10.	m	89	178	12	2	3	3	1	1	2	16	2	3	3	2	3	3
11.	m	98	184	6	1	1	1	1	1	1	10	1	3	2	1	1	1
12.	f	92	183	6	1	1	1	1	1	1	8	1	1	2	1	2	1
13.	f	95	175	11	1	3	1	1	2	2	12	1	3	2	1	2	3
14.	m	124	184	16	2	3	3	4	2	2	21	2	3	4	4	4	4
15.	f	108	184	10	2	3	1	1	2	1	13	2	1	2	2	3	3
16.	m	112	181	11	2	3	1	1	2	2	14	2	3	2	2	3	3
17.	m	107	184	6	1	1	1	1	1	1	11	2	3	2	1	2	1
18.	f	-	184	11	2	3	2	1	2	1	11	2	3	2	1	2	1
19.	f	96	175	8	1	3	1	1	1	1	13	2	3	2	1	2	3
20.	f	89	194	6	1	1	1	1	1	1	8	2	1	1	1	1	2
21.	f	106	182	5	0	1	1	1	1	1	10	2	3	2	1	1	1
22.	f	109	181	7	2	1	1	1	1	1	8	1	1	2	2	1	1
23.	f	126	176	8	2	1	2	2	1	1	10	1	1	2	1	2	3
24.	f	-	198	8	1	3	1	1	1	1	7	2	1	1	1	1	1
25.	m	-	188	10	2	3	2	1	1	1	15	2	3	3	1	3	3
26.	f	123	184	14	2	3	3	2	2	1	17	2	3	3	3	3	3
27.	f	116	181	9	2	3	2	1	1	1	10	1	3	2	2	1	1
28.	f	105	186	9	2	1	1	1	2	2	10	1	3	2	1	2	1
29.	f	90	183	6	1	1	1	1	1	1	7	1	1	2	1	1	1
30.	f	101	183	8	1	3	1	1	1	1	8	1	3	1	1	1	1

TABLE 7

NINTH GRADE INTRODUCTORY PHYSICAL SCIENCE

Pupil No.	Sex	I.Q.	C.A.	C.S. I	I SA	I V	I RI	I EC	I SV	I E	C.S. II	II SA	II V	II RI	II EC	II SV	II E
1.	m	129	173	15	2	3	3	1	3	2	18	2	3	4	4	3	2
2.	m	117	185	13	1	1	3	2	3	3	18	2	3	3	4	3	3
3.	m	114	177	7	1	1	2	1	1	1	15	2	3	3	1	3	3
4.	m	109	196	10	2	3	1	1	2	1	14	2	3	2	3	2	2
5.	f	86	181	9	1	3	1	1	2	1	18	2	3	3	3	3	4
6.	m	109	185	12	2	3	1	2	3	1	15	2	3	2	3	3	2
7.	m	118	181	11	2	3	1	3	1	1	17	2	3	3	3	3	3
8.	m	95	183	10	2	3	1	1	1	2	15	2	3	3	3	2	2
9.	m	127	175	16	2	3	2	3	3	3	20	2	3	3	4	4	4
10.	f	110	174	14	2	3	3	3	1	2	16	2	3	3	3	3	2
11.	f	101	184	13	1	3	2	2	3	2	18	1	3	3	4	4	3
12.	m	110	186	9	1	3	1	1	2	1	14	2	3	2	2	3	2
13.	m	118	185	12	2	3	1	2	3	1	16	2	3	2	3	3	3
14.	m	119	181	11	2	3	1	2	1	2	17	2	3	4	4	2	2
15.	f	96	183	10	2	3	1	1	1	2	19	2	3	3	3	4	4
16.	f	124	177	10	2	3	2	1	1	1	17	2	3	4	4	2	2
17.	f	110	175	11	2	3	1	1	1	2	17	2	3	3	3	3	3
18.	f	108	178	6	1	1	1	1	1	1	12	2	3	2	2	2	1
19.	f	108	182	10	2	3	1	1	1	2	16	2	3	3	3	2	3
20.	m	92	198	11	1	3	2	1	2	2	18	2	3	4	3	4	3
21.	f	94	185	7	1	1	1	1	1	2	13	2	3	2	2	2	2
22	m	122	182	18	2	3	4	4	3	2	21	2	3	4	4	4	4
23.	m	-	176	9	1	3	1	2	1	1	16	2	3	3	3	3	2
24.	f	98	177	12	2	1	1	1	3	3	16	2	3	2	3	3	3
25.	m	106	180	12	2	3	2	1	3	2	17	2	3	4	3	3	2
26.	m	123	175	11	2	3	1	3	1	1	18	2	3	4	4	3	2
27.	f	120	175	9	2	3	1	1	1	1	16	2	3	2	2	3	4
28.	m	99	184	14	2	3	3	1	2	3	20	2	3	4	4	4	3
29.	f	107	177	7	1	1	1	1	2	1	10	1	1	1	1	3	2
30.	f	104	180	14	2	3	3	1	2	3	20	2	3	4	4	4	3

TABLE 8

NINTH GRADE EARTH SCIENCE CURRICULUM PROJECT

Pupil No.	Sex	I.Q.	C.A.	C.S. I	I SA	I V	I RI	I EC	I SV	I E.	C.S. II	II SA	II V	II RI	II EC	II SV	II E
1.	m	120	183	9	2	3	1	1	1	1	17	2	3	3	2	3	4
2.	m	126	177	16	2	3	4	2	3	2	14	2	3	3	1	2	3
3.	m	123	175	15	2	3	4	2	2	2	18	2	3	3	4	2	3
4.	f	108	185	13	2	1	3	1	3	3	18	2	3	4	3	2	4
5.	f	120	184	10	2	1	1	2	2	2	8	2	1	1	1	3	1
6.	m	90	184	9	2	1	1	1	3	1	15	2	3	2	3	3	2
7.	m	108	176	9	2	3	1	1	1	1	11	1	3	2	1	2	2
8.	f	101	182	8	2	1	1	1	1	2	14	2	3	2	2	3	2
9.	m	126	183	11	1	3	2	1	2	2	14	2	3	2	2	3	2
10.	m	101	185	7	2	1	1	1	1	1	10	2	3	2	1	1	1
11.	f	124	180	8	2	1	1	1	2	1	12	2	3	2	1	2	2
12.	m	125	177	16	2	3	2	4	2	3	16	2	3	2	4	2	3
13.	m	96	179	11	2	3	1	2	1	1	13	2	3	2	2	2	2
14.	f	116	176	9	2	1	1	1	2	2	12	2	3	1	1	3	2
15.	f	83	184	9	2	3	1	1	1	1	9	1	3	1	1	1	2
16.	f	107	180	10	1	3	1	2	2	1	12	2	3	2	3	1	1
17.	m	120	184	8	2	3	1	2	2	1	14	2	3	2	4	2	1
18.	m	110	185	11	2	3	1	2	2	1	14	2	3	2	4	2	1
19.	m	113	186	11	2	3	1	2	2	1	16	2	3	2	4	3	2
20.	f	118	187	8	1	1	1	2	2	1	13	2	3	2	3	2	1
21.	f	123	180	11	2	3	3	1	1	1	15	2	3	2	2	3	3
22.	f	109	181	7	2	1	1	1	1	1	12	1	3	1	2	3	2
23.	f	136	184	9	1	1	1	1	2	3	15	2	3	2	2	3	3
24.	f	111	175	8	2	1	1	1	2	1	12	2	3	2	2	2	1
25.	f	113	174	10	2	3	2	1	2	1	13	2	3	2	2	2	2
26.	m	112	174	12	2	3	2	2	2	1	11	2	3	2	2	1	1
27.	m	110	177	13	2	3	3	1	2	2	12	2	3	1	1	3	2
28.	f	119	185	11	2	3	1	1	2	2	17	2	3	4	2	2	4
29.	f	119	185	12	2	3	2	2	2	1	15	2	3	4	1	3	2
30.	f	103	119	10	2	1	2	1	2	2	17	2	3	2	4	2	4

Tables 9 and 10 summarize the results of the testing program. Since there are differences in the pretest scores of the various groups, the data were analyzed in terms of the gain in score, i.e., the posttest score minus the pretest-score. In some cases the gains in Conservation of Solid Amount and Conservation of Volume are small compared with the gains in the other tasks because many individuals conserved in these areas on the pretest and thus showed no gain. The results are shown graphically on Graphs 3-13.

TABLE 9

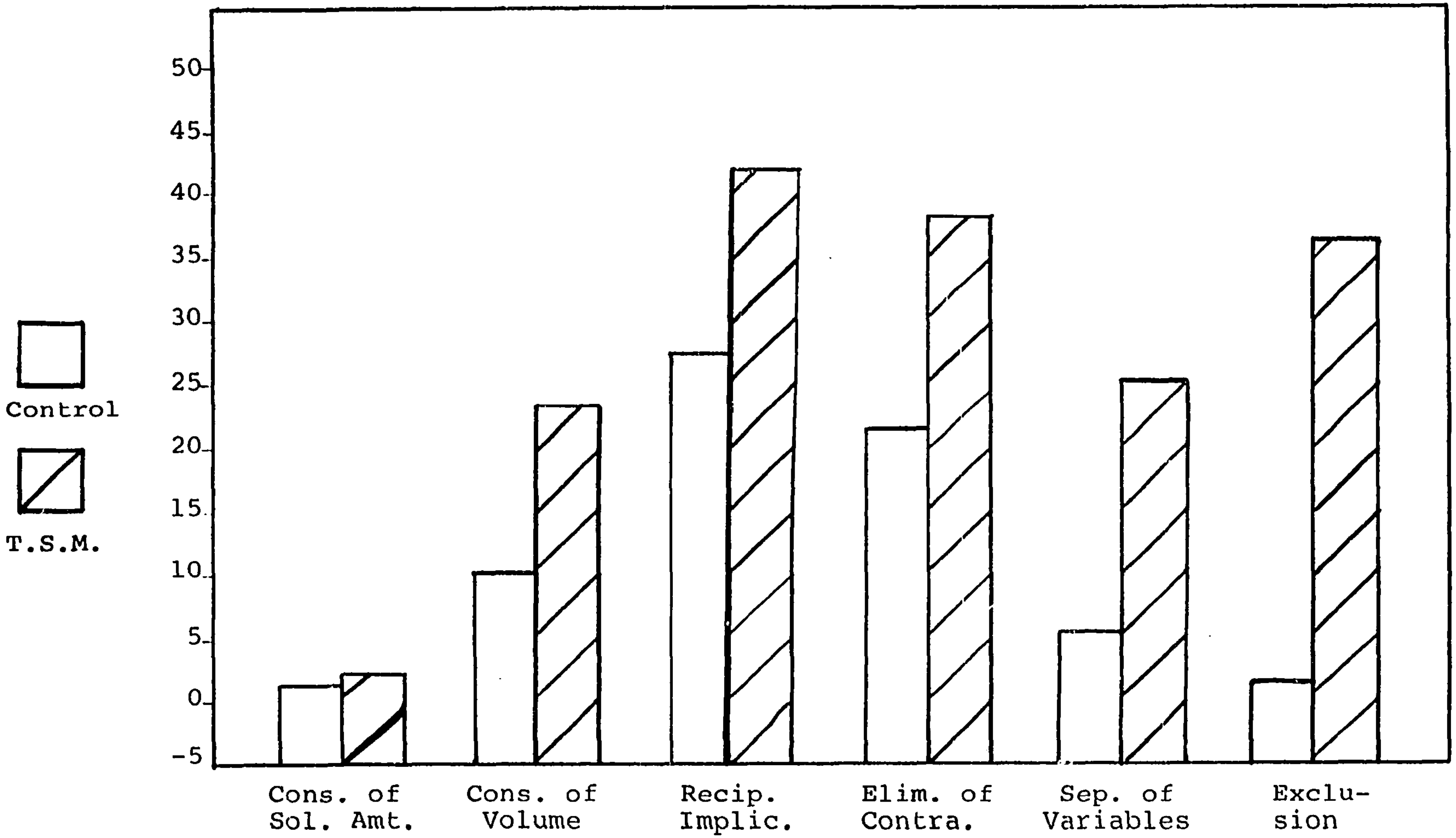
PRETEST AND POSTTEST SCORES FOR CONTROL AND EXPERIMENTAL GROUPS

	Control 8	ESCP 8	IPS 8	TSM 8	Control 9	ESCP 9	IPS 9
Pre-test	312	288	278	301	265	308	319
Post-test	382	318	375	433	335	427	465
Gain	60	30	97	132	70	119	146

TABLE 10

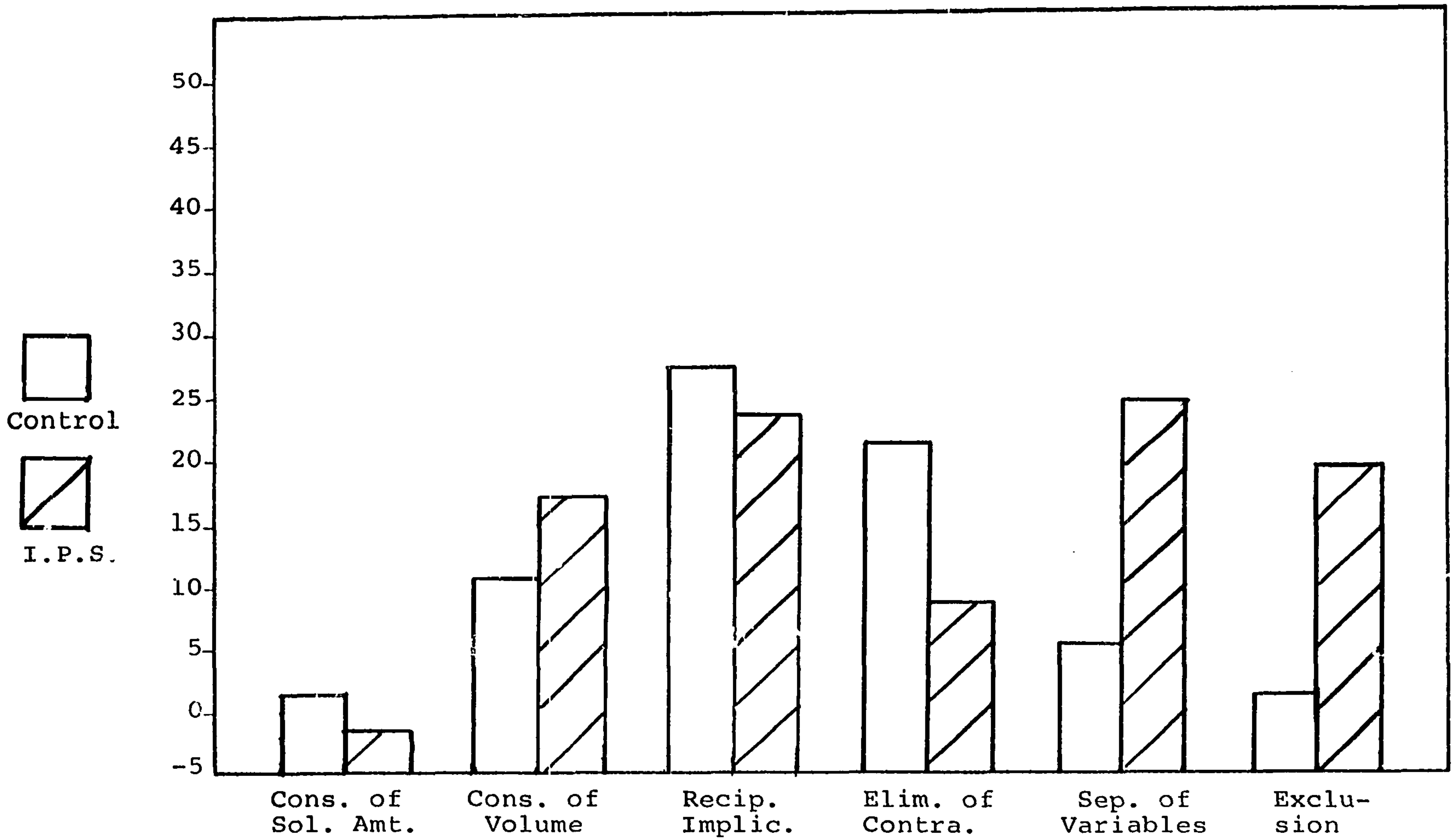
GAIN IN SCORES FOR CONTROL AND EXPERIMENTAL GROUPS CLASSIFIED BY TASK

Task	Control 8	ESCP 8	IPS 8	TSM 8	Control 9	ESCP 9	IPS 9
Conservation of Solid Amount	1	-1	-2	2	2	1	8
Conservation of Volume	10	10	17	23	4	23	11
Reciprocal Implications	27	27	23	42	18	17	38
Elimination of Contradictions	21	1	8	38	7	23	46
Separation of Variables	5	10	24	25	16	11	35
Operations of Exclusion	1	1	19	36	19	19	27



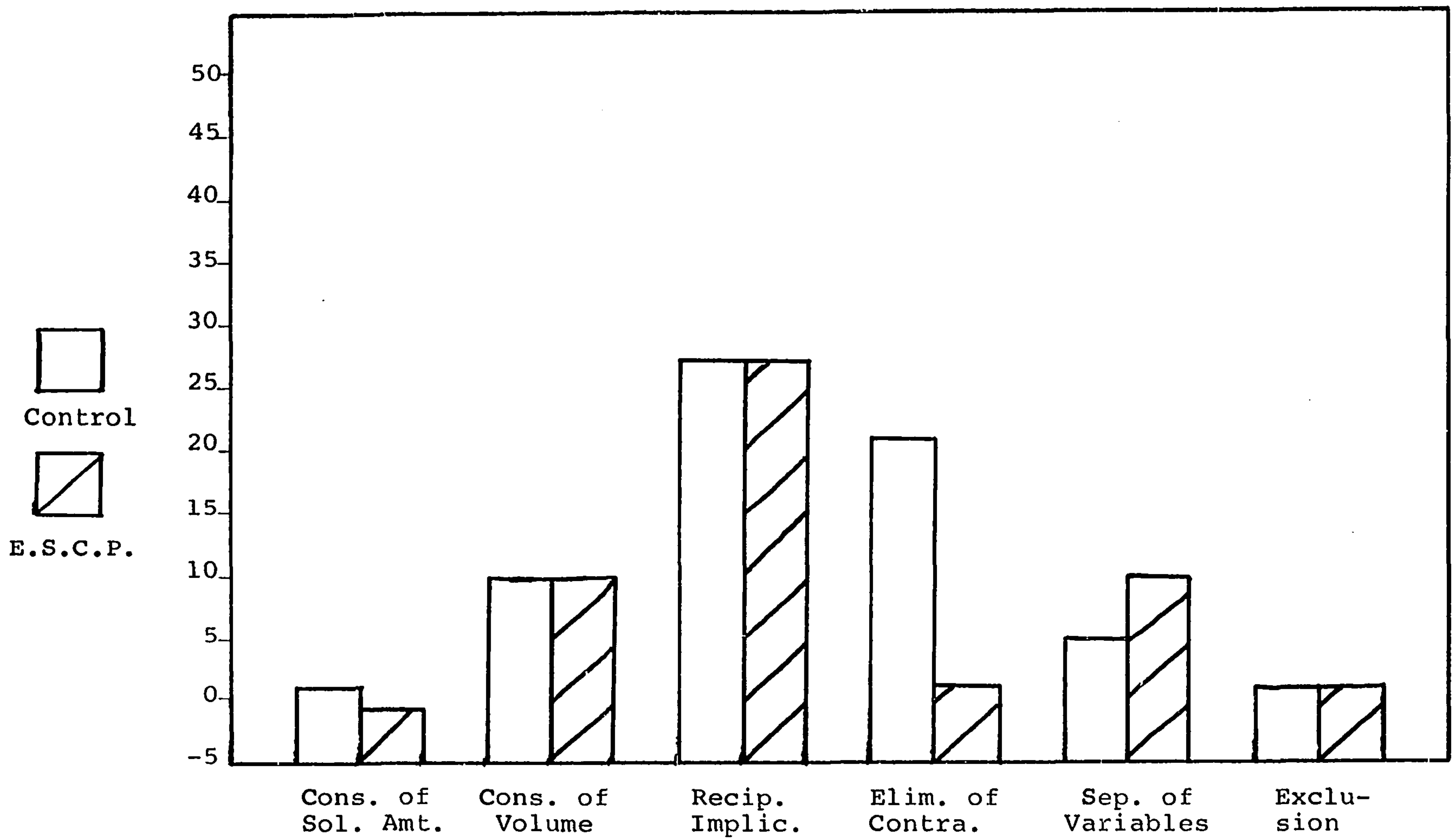
GRAPH 3

COMPARISON OF GAIN IN SCORES
EIGHTH GRADE CONTROL - EIGHTH GRADE T.S.M.



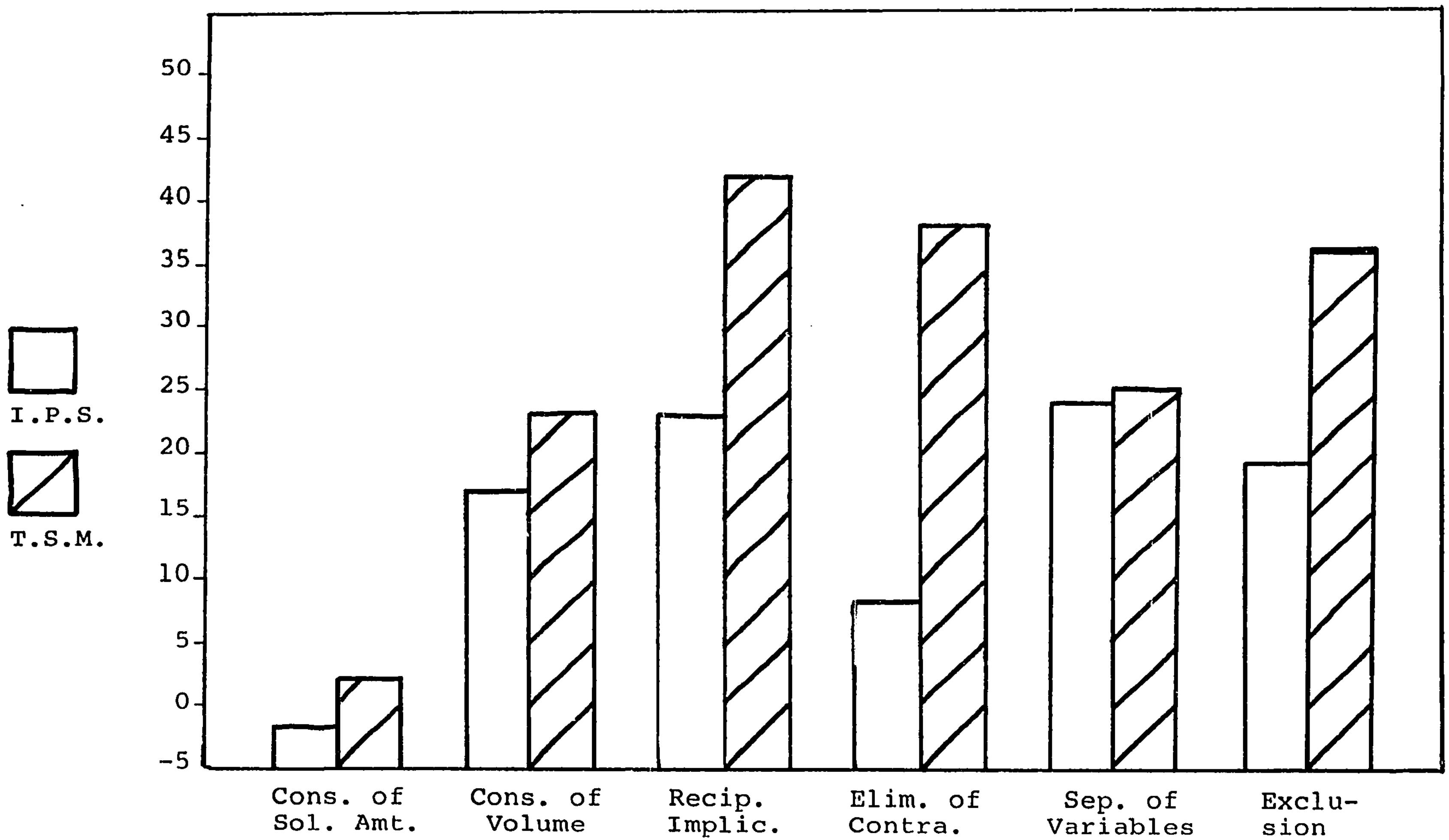
GRAPH 4

COMPARISON OF GAIN IN SCORES
EIGHTH GRADE CONTROL - EIGHTH GRADE I.P.S.



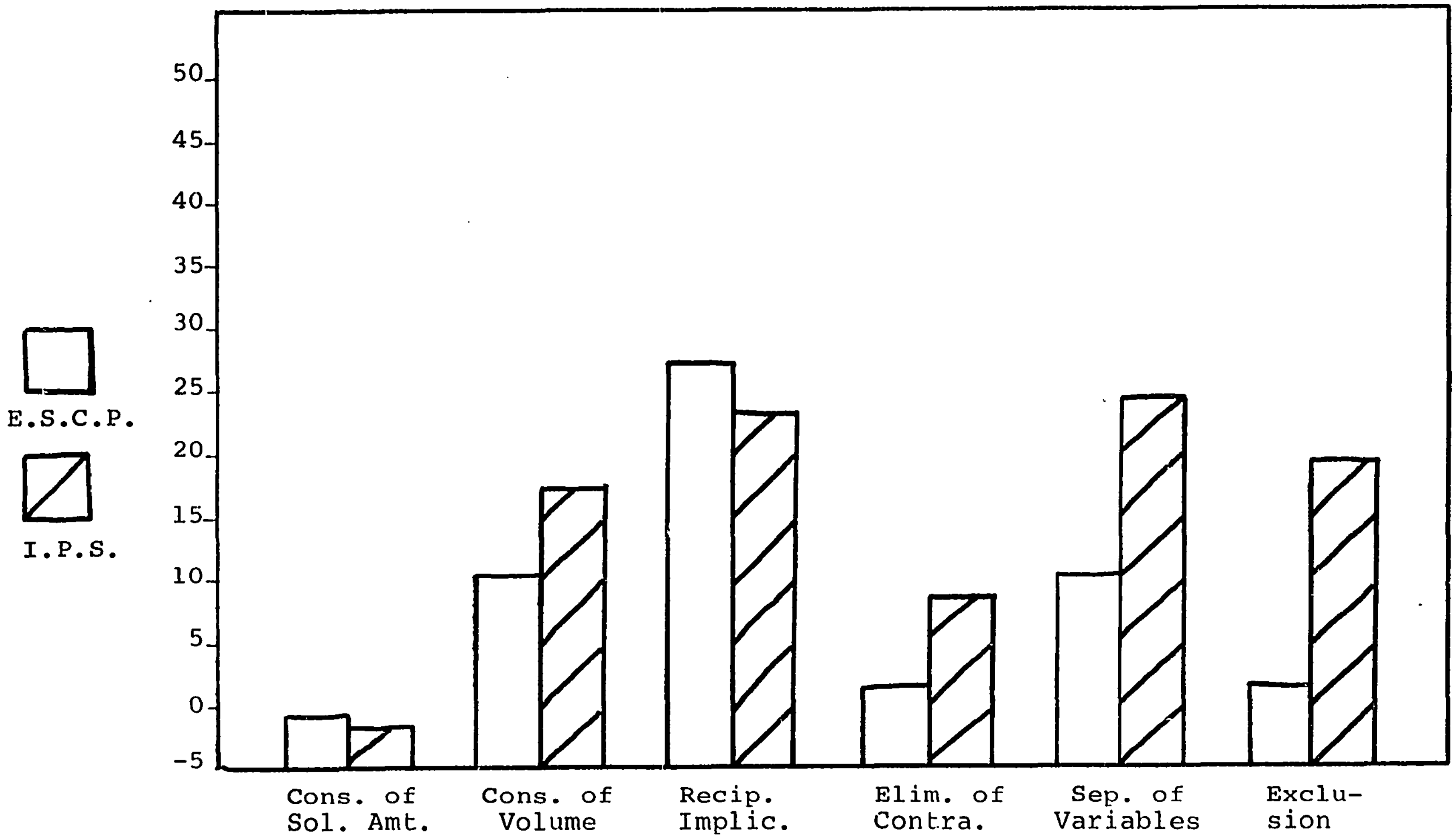
GRAPH 5

COMPARISON OF GAIN IN SCORES
EIGHTH GRADE CONTROL - EIGHTH GRADE E.S.C.P.



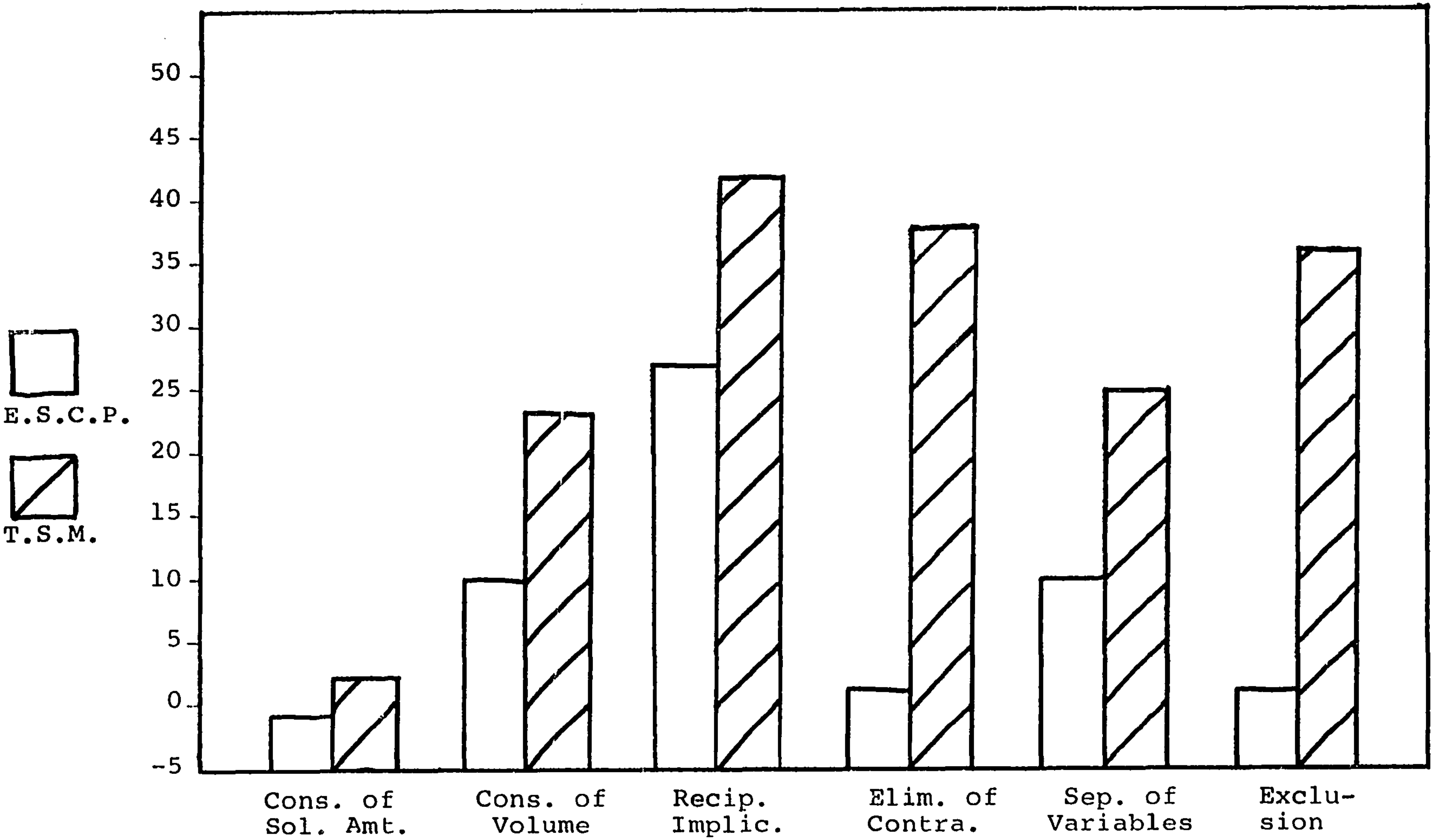
GRAPH 6

COMPARISON OF GAIN IN SCORES
EIGHTH GRADE I.P.S. - EIGHTH GRADE T.S.M.



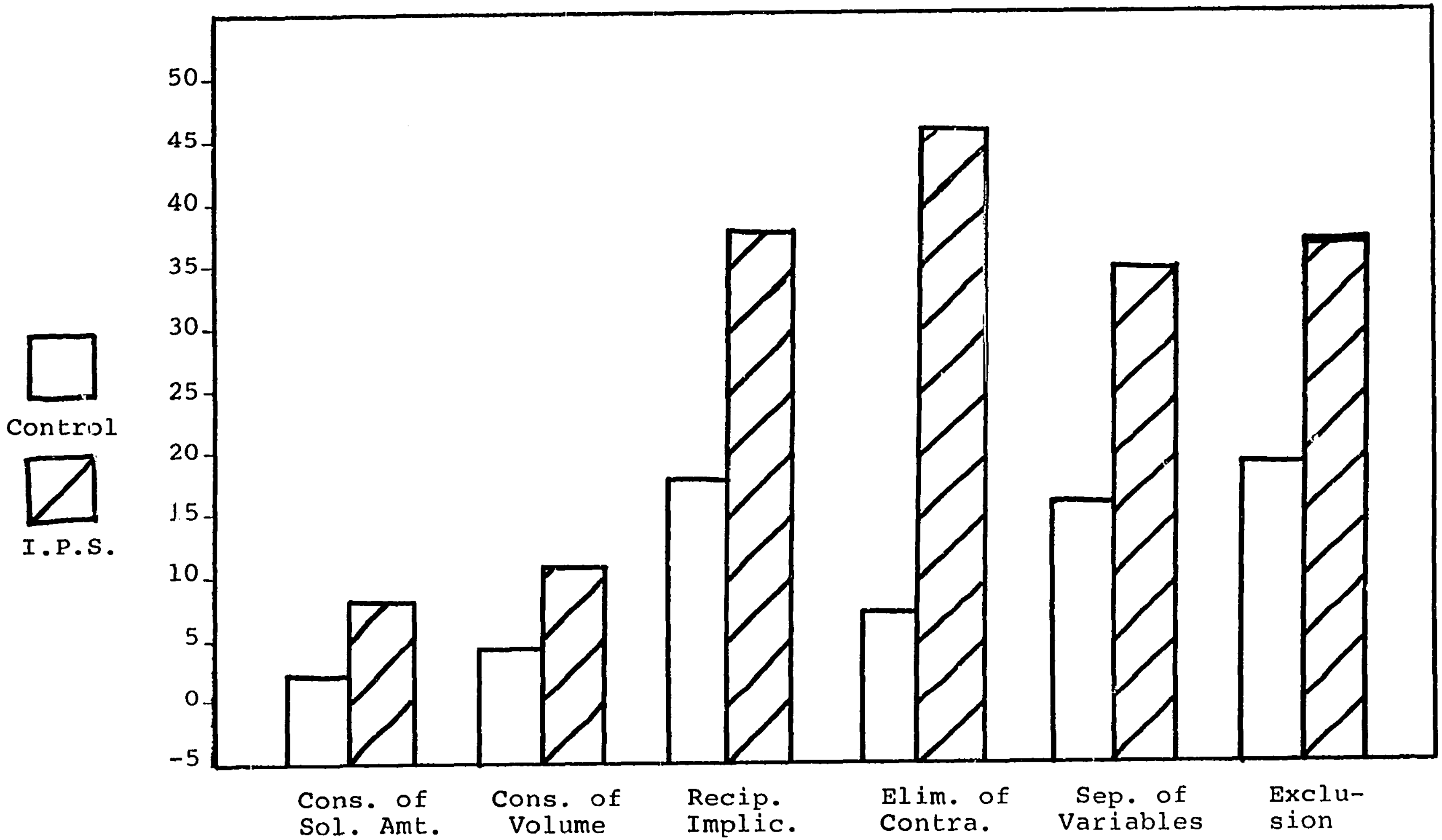
GRAPH 7

COMPARISON OF GAIN IN SCORES
EIGHTH GRADE E.S.C.P. - EIGHTH GRADE I.P.S.



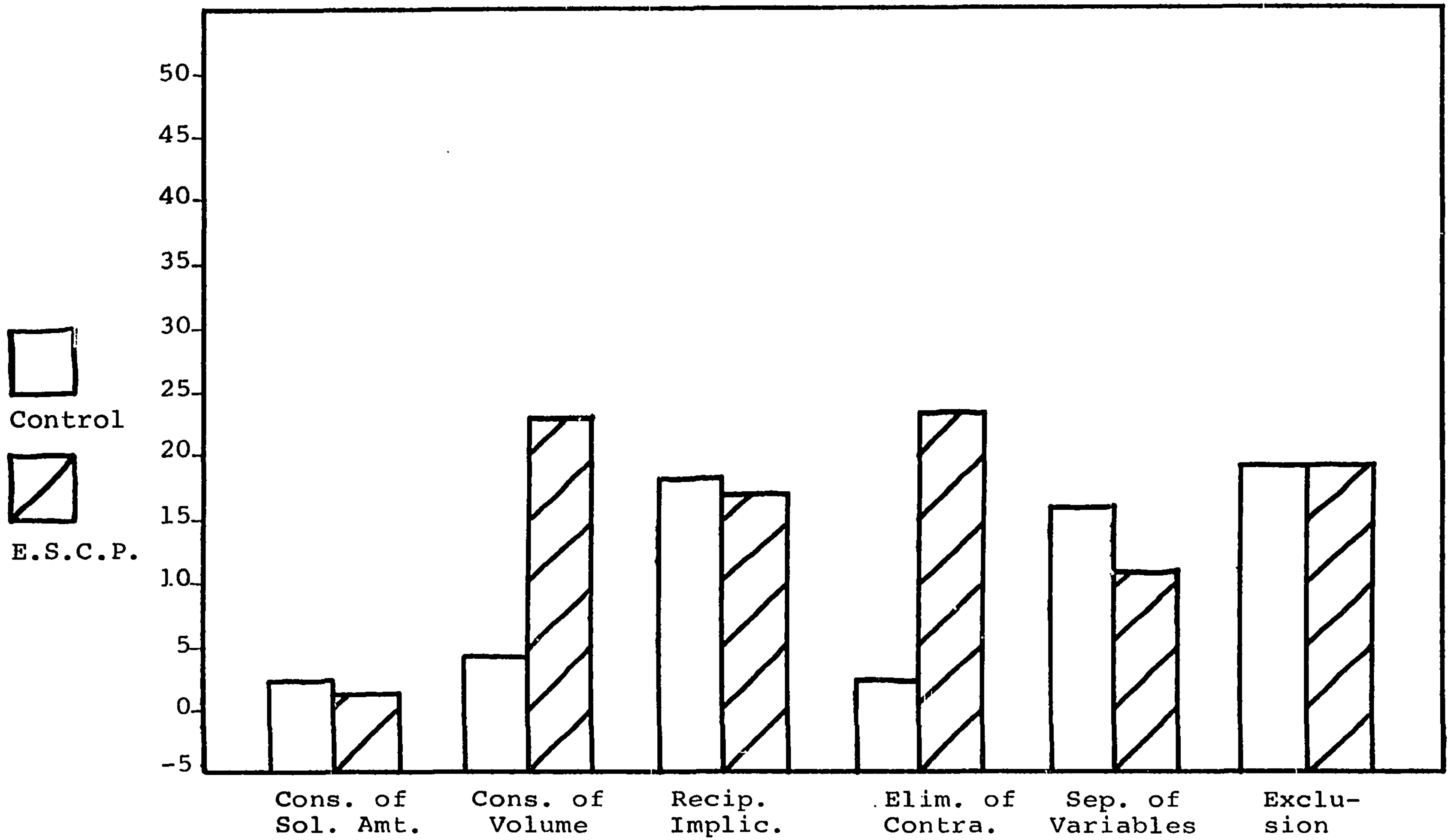
GRAPH 8

COMPARISON OF GAIN IN SCORES
EIGHTH GRADE E.S.C.P. - EIGHTH GRADE T.S.M.



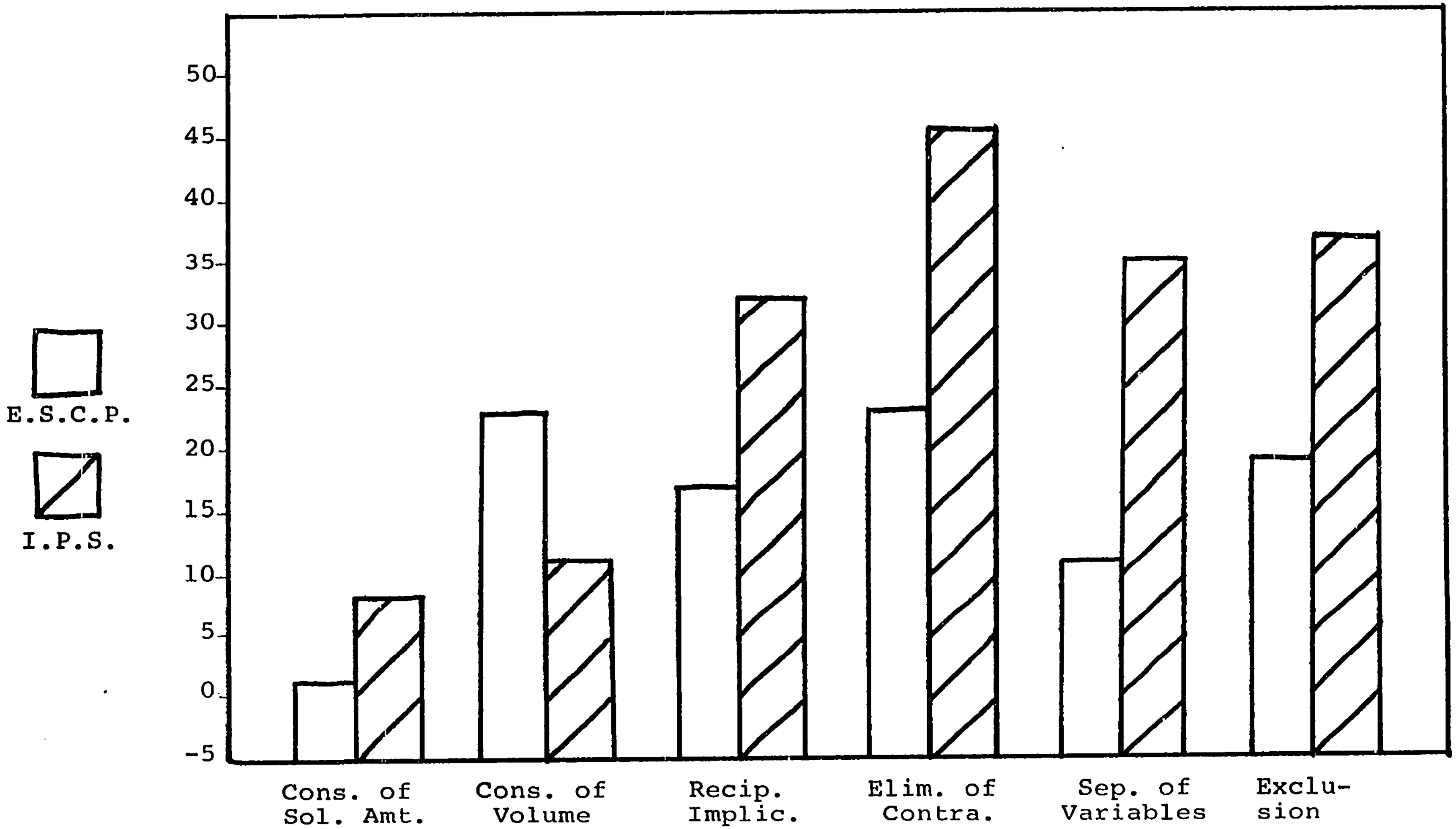
GRAPH 9

COMPARISON OF GAIN IN SCORES
NINTH GRADE CONTROL - NINTH GRADE I.P.S.



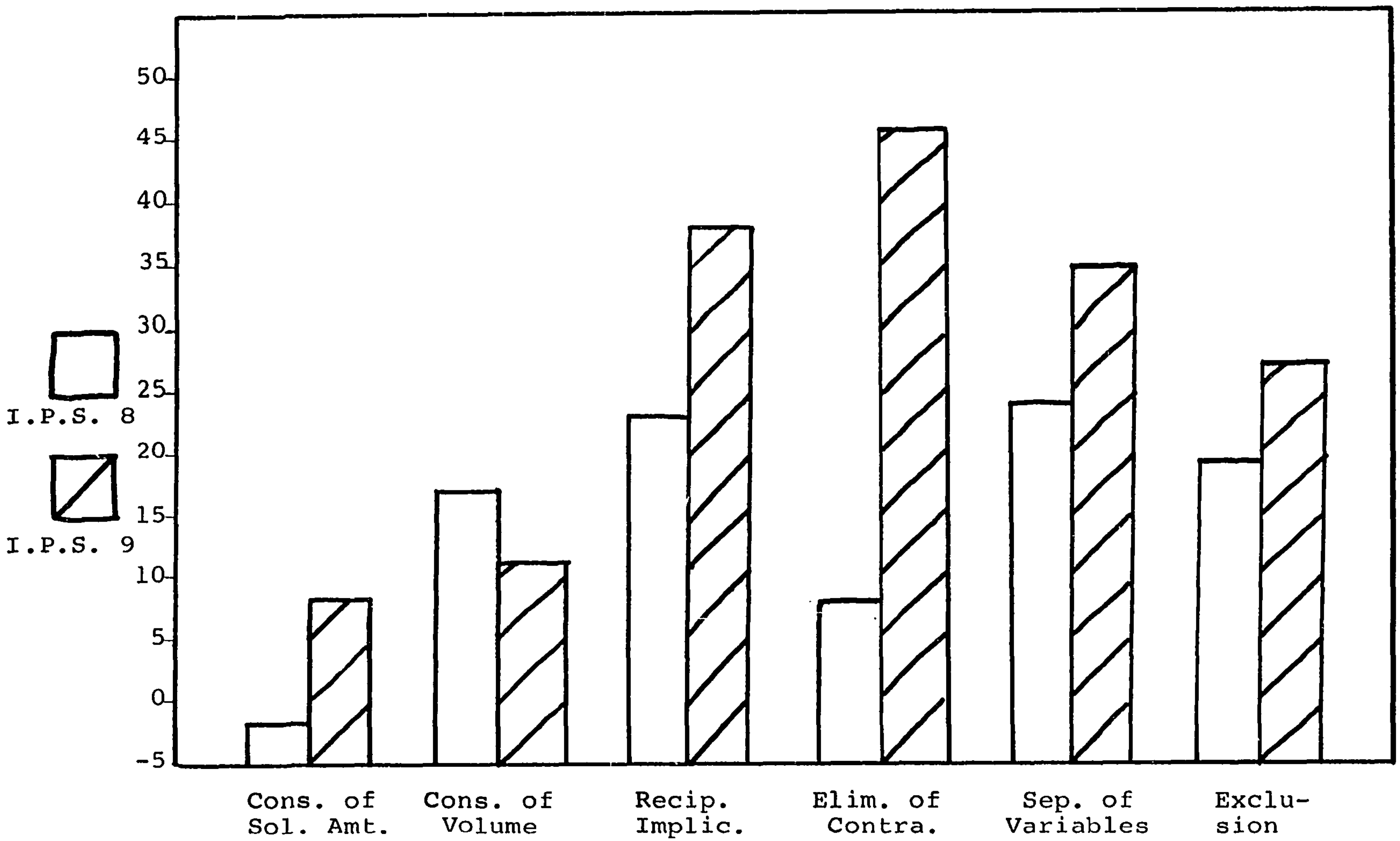
GRAPH 10

COMPARISON OF GAIN IN SCORES
NINTH GRADE CONTROL - NINTH GRADE E.S.C.P.



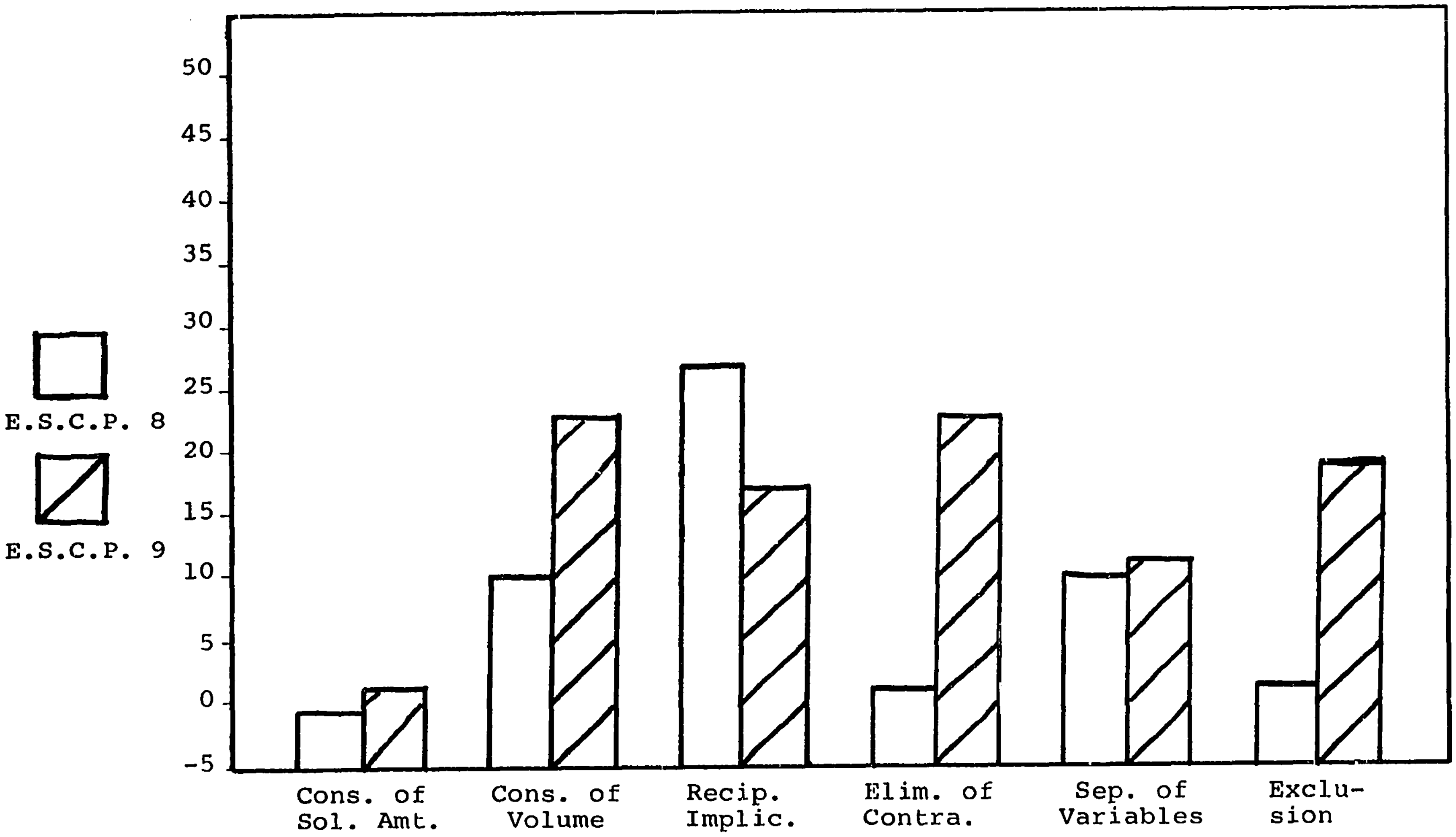
GRAPH 11

COMPARISON OF GAIN IN SCORES
NINTH GRADE E.S.C.P. - NINTH GRADE I.P.S.



GRAPH 12

COMPARISON OF GAIN IN SCORES
EIGHTH GRADE I.P.S. - NINTH GRADE I.P.S.



GRAPH 13

COMPARISON OF GAIN IN SCORES
EIGHTH GRADE E.S.C.P. - NINTH GRADE E.S.C.P.

TABLE 11

ANALYSIS-OF-COVARIANCE VALUES AND INDICATION OF SIGNIFICANCE AT 0.10 LEVEL FOR EXPERIMENTAL GROUPS COMPARED WITH CONTROL GROUPS

Hypothesis	Graph No.	F-Value Obtained	F-Table Value	Indication of Significance	In Favor of
Control 8- TSM 8	3	3.57	2.84	yes	TSM
Control 8- IPS 8	4	1.05	2.84	no	Neither
Control 8- ESCP 8	5	-7.4	2.84	yes	Control
IPS 8- TSM 8	6	21	2.84	yes	TSM
ESCP 8- IPS 8	7	41	2.84	yes	IPS
ESCP 8- TSM 8	8	57	2.84	yes	TSM
Control 9 IPS 9	9	24	2.84	yes	IPS
Control 9- ESCP 9	10	22	2.84	yes	ESCP
ESCP 9- IPS 9	11	4.9	2.84	yes	IPS
IPS 8- IPS 9	12	26	2.84	yes	IPS 9
ESCP 8- ESCP 9	13	147	2.84	yes	ESCP 9

The F-values in Table 11 were computed using the numerical difference in the scores (posttest-pretest). The differences between the scores were compared using the formulas given in Appendix D.

The correlation between performance on the formal operational tasks and I.Q. was made by comparing the gain in score (posttest-pretest) of each individual to his I.Q. Five of the participating groups had been tested using the California Test of Mental Maturity Short Form Level Three. Percentile scores were obtained for the CTMM Short Form Level Three, and the CTMM Level Two, 1963 Edition, and the Science Research Associates Intelligence Evaluation, the tests used by the other two groups. The scores of the other two groups were then adjusted to the CTMM Short Form Level Three scores. The coefficient of Correlation between gain and I.Q. was .34.

The determination of operational level was made by considering a score of 12 or below to indicate concrete operations, scores of 13 or 14 to be indicative of a transitional stage and a score of 15 or greater indicative of formal operations. The results are shown in Table 12.

TABLE 12

OPERATIONAL LEVEL OF JUNIOR HIGH SCHOOL LEARNERS

Curriculum and Grade Level	Concrete Operations		Transitional Stage		Formal Operations	
	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
Eighth Grade General Science	22	13	7	6	1	10
Eighth Grade E.S.C.P.	25	24	4	4	1	2
Eighth Grade I.P.S.	27	17	2	6	1	7
Eighth Grade T.S.M.	23	5	1	2	2	24
Ninth Grade General Science	28	20	1	5	1	5
Ninth Grade I.P.S.	22	2	5	3	3	25
Ninth Grade E.S.C.P.	25	11	2	8	3	11
Total	172	92	26	34	12	84
Percentage of Total	82	44	12	16	6	40

CHAPTER IV

INTREPRETATION OF THE DATA

The presentation of the data in the form of tables and graphs in Chapter III showed trends and patterns which can be interpreted by using those tables and graphs collectively. The trends will be examined in this chapter to see if the general questions asked in Chapter I have been answered. Can we evaluate differences in the development of the ability to solve problems in a logical manner? Are the tasks chosen for this study, as described in Appendix A, useful in performing such evaluations?

More specifically, will junior high school students exposed to science courses which allow them to interact with their physical environment through inquiry show more progress in moving toward the attainment of formal operations than do students enrolled in a traditional, lecture-demonstration type science class? The results of the evaluation of logical thinking ability of students taking several inquiry-centered curricula were compared with students at the same grade level exposed to lecture-demonstration type courses. Two comparisons for the same courses (IPS and ESCP) were also made between grade levels. These data will be evaluated to provide answers to the specific hypotheses stated in Chapter II.

The results of statistical analyses are considered to be valid indicators of trends in the data; they are not, however, the only such indicator. The hypotheses were tested at the 0.10 level so as not to risk accepting the null hypothesis if it is actually false. To do so would impede the further development and implementation of inquiry-type courses. (See page 13.)

Comparison of the Samples

Table 9 shows the total pretest and posttest scores for the control and experimental groups and the gain in the scores of the posttest compared with the pretest. Each group made a net gain from pretest to posttest which would follow from Piaget's statement that one of the factors involved in the intellectual development necessary for formal thinking is the development of the body as a whole as well as the development of the nervous system and mental functions. The gain in score of the experimental group is greater than that of the control group in all except one case. Coupling this fact with the description of activities in the experimental courses as allowing students interacting with their physical environment and with each other, two additional causual agents listed by Piaget as aiding in the development of formal structures, allows the statement to be made that logical thinking ability can be evaluated and that the tasks used in this study are valuable in performing this evaluation. (See Appendix A for a description of the tasks and Appendix B for further validation of the efficacy of these tasks in making such evaluations.)

Eighth-Grade Time, Space and Matter

Comparison of the eighth-grade control group and the eighth-grade T.S.M. group as shown on Graph 3 and Tables 9, 10, and 11, indicates that the gain in attainment of formal operations by the T.S.M. group exceeds that of the control group by more than 100 per cent. A comparison of individual tasks shows that the T.S.M. group gained more than the control group in each area evaluated. The F-value obtained (3.57, Table 11) was significant at the 0.10 level. On the basis of these data, the hypothesis that there is no significant difference in the rate of attainment of formal operations by eighth-grade pupils who take a science course using *Time, Space and Matter* materials and those who take general science (Hypothesis I, Chapter II) can be rejected in favor of the experimental group.

Eighth-Grade Introductory Physical Science

Comparison of the eighth-grade control group and the eighth-grade I.P.S. group as shown in Graph 4 and Tables 9, 10, and 11 indicates that the gain in attainment of formal operations by the I.P.S. group exceeds that of the control group by a total of more than 50 per cent. A comparison of individual tasks shows the I.P.S. group gaining more than the control group on three of the six tasks. The F-value obtained was positive (1.05, Table 11) but was not significant at the 0.10 level. On the basis of this data, the hypothesis that there is no significant difference in the rate of attainment of formal operations by eighth-grade pupils who take a science course using Introductory Physical Science and those who take general science (Hypothesis 3, Chapter II) cannot be rejected.

Eighth-Grade Earth Science Curriculum Project

Comparison of the eighth-grade control group and the eighth-grade E.S.C.P. group as shown in Graph 4 and Tables 9, 10, and 12 indicates that the gain in attainment of formal operational thought by the E.S.C.P. group is only half as great as that of the control group. The experimental group score exceeded the control group score in only one area, Separation of Variables. Since the control group achieved higher than did the experimental group, and a negative F value was obtained (-7.4, Table 11) the hypothesis that there is no significant difference in the rate of attainment of formal operations by eighth-grade pupils who take a science course using Earth Science Curriculum Project materials and those who take general science (Hypothesis 2, Chapter II) can be rejected in favor of the control group.

Eighth-Grade *Introductory Physical Science* Compared with Eighth-Grade *Time, Space and Matter*

Comparison of the eighth-grade I.P.S. group and the eighth-grade T.S.M. group as shown in Graph 6 and Tables 9, 10, and 11 indicates that the gain in attainment of formal operations by the T.S.M. group exceeds that of the I.P.S. group by more than 100 per cent. A comparison of individual tasks shows that the T.S.M. group gained more than the I.P.S. group in all six areas evaluated. The F-value obtained, (21, Table 11) was significant at the 0.001 level. On the basis of these data, the hypothesis that there is no significant difference in the attainment of formal operations by eighth grade pupils who take a science course using *Introductory Physical Science* materials and those who take a science course using *Time, Space and Matter* materials (Hypothesis 4, Chapter II) can be rejected in favor of the *Time, Space and Matter* group.

Eighth-Grade Earth Science Curriculum Project Compared with Eighth-Grade *Introductory Physical Science*

Comparison of the eighth-grade I.P.S. group and the eighth-grade E.S.C.P. group as shown on Graph 7 and Tables 9, 10, and 11 indicates that the gain in attainment of formal operations by the I.P.S. group exceeds that of the E.S. C.P. group by more than 200 per cent. A comparison of individual tasks shows that the I.P.S. group gained more than the E.S.C.P. group in four of the six areas evaluated. The F-value obtained (41, Table 11) was significant at the 0.001 level. On the basis of these data, the hypothesis that there is no significant difference in the attainment of formal operations by eighth-grade pupils who take a science course using Introductory Physical Science materials and those who take a science course using Earth Science Curriculum Project materials (Hypothesis 5, Chapter II) can be rejected in favor of the Introductory Physical Science group.

Eighth-Grade Earth Science Curriculum Project Compared with Eighth-Grade Time, Space and Matter

Comparison of the eighth-grade E.S.C.P. group and the eighth-grade T.S.M. group as shown in Graph 8 and Tables 9,10, and 11 indicates that the gain in attainment of formal operations by the T.S.M. group exceeds that of the E.S.C.P. group by more than 400 per cent. A comparison of individual tasks shows that the T.S.M. group gained more than the E.S.C.P. group in all six areas evaluated. The F-value Obtained, (57, Table 11) was significant at the 0.001 level. On the basis of these data, the hypothesis that there is no significant difference in the attainment of formal operations by eighth-grade pupils who take a science course using Time, Space and Matter materials and those who take a science course using Earth Science Curriculum Project materials (Hypothesis 6, Chapter II) can be rejected in favor of the Time, Space and Matter group.

Ninth-Grade Introductory Physical Science

Comparison of the ninth-grade control group and the ninth-grade I.P.S. group as shown in Graph 9 and Tables 9, 10, and 11 indicates that the gain in formal operations by the I.P.S. group exceeds that of the control group by more than 100 per cent. A comparison of individual tasks showed that the I.P.S. group gained more than the control group in each area evaluated. The F-value obtained (24, Table 11) was significant at the 0.001 level. On the basis of these data, the hypothesis that there is no significant difference in the rate of attainment of formal operations by ninth-grade pupils who take Introductory Physical Science and those who take general science (Hypothesis 7, Chapter II) can be rejected in favor of the experimental group.

Ninth-Grade Earth Science Curriculum Project

Comparison of the ninth-grade control group and the ninth-grade Earth Science Curriculum Project group as shown in Graph 10 and Tables 9, 10, and 11 indicates that the gain in formal operations of the E.S.C.P. group exceeds that of the control group by almost 60 per cent. A comparison of individual tasks showed that the control group gained more than the E.S.C.P. group on three of the six tasks. However, the gains made by the control group were small compared to the gains made by the E.S.C.P. group in the areas where they excelled. The F-value obtained, (22, Table 11) was significant at the 0.001 level. On the basis of these data, the hypothesis that there is no significant difference in the rate of attainment of formal operations by ninth-grade pupils who take a science course using Earth Science Curriculum Project materials and those who take general science (Hypothesis 8, Chapter II) can be rejected in favor of the experimental group.

Ninth-Grade Earth Science Curriculum Project Compared with Ninth-Grade *Introductory Physical Science*

Comparison of the ninth-grade I.P.S. group and the ninth-grade E.S.C.P. group as shown on Graph 11 and Tables 9, 10, and 11 indicates that the gain in formal operations by the I.P.S. group exceeds that of the E.S.C.P. group by more than 20 per cent. A comparison of individual tasks showed that the I.P.S. group gained more than the E.S.C.P. group in five of the six areas evaluated. The F-value obtained (4.9, Table 11) was significant at the 0.05 level. On the basis of these data, the hypothesis that there is no significant difference in the attainment of formal operations by ninth-grade pupils who take a science course using Earth Science Curriculum Project materials and those who take a science course using *Introductory Physical Science* materials (Hypothesis 9, Chapter II) can be rejected in favor of the *Introductory Physical Science* Group.

Eighth-Grade Introductory Physical Science Compared with Ninth-Grade Introductory Physical Science

Comparison of the eighth-grade I.P.S. group and the ninth-grade I.P.S. group as shown on Graph 12 and Tables 9, 10, and 11 indicates that the gain in formal operations by the ninth-grade I.P.S. group exceeds that of the eighth-grade I.P.S. group by more than 50 per cent. A comparison of individual tasks showed that the ninth-grade I.P.S. group gained more than the eighth-grade I.P.S. group in five of the six areas evaluated. The F-value obtained (26, Table 11) was significant at the 0.001 level. On the basis of these data the hypothesis that there is no significant difference in the rate of attainment of formal operations by eighth-grade pupils who take a science course using Introductory Physical Science materials and ninth-grade pupils who take a science course using Introductory Physical Science materials (Hypothesis 10, Chapter II) can be rejected in favor of the ninth-grade Introductory Physical Science group.

Eighth-Grade Earth Science Curriculum Project Compared with Ninth-Grade Earth Science Curriculum Project

Comparison of the eighth-grade E.S.C.P. group and the ninth-grade E.S.C.P. group as shown in Graph 13 and Tables 9, 10, and 11 indicates that the gain in formal operations by the ninth grade E.S.C.P. group exceeds that of the eighth-grade E.S.C.P. group by more than 400 per cent. A comparison of individual tasks shows that the ninth-grade E.S.C.P. group gained more than the eighth-grade E.S.C.P. group in five of the six areas evaluated. The F-value obtained (147, Table 11) was significant at the 0.001 level. On the basis of these data the hypothesis that there is no significant difference in the rate of attainment of formal operations by eighth-grade pupils who take a science course using Earth Science Curriculum Project materials and ninth-grade pupils who take a science course using Earth Science Curriculum Project materials can be rejected in favor of the ninth-grade Earth Science Curriculum Project group.

Sex

Comparison of the scores made by the males and those made by the females as shown in Table 11 indicates that the F-value (1.76) was not significant. Therefore, the hypothesis that there is no significant difference in the rate of attainment of formal operations by junior high school boys compared with junior high school girls (Hypothesis 12, Chapter II) cannot be rejected.

I.Q.

Correlation between acquisition of formal operations and I.Q. was made by comparing the gain in score (Posttest-Pretest) of each individual with his I.Q. as shown in Table 2 through Table 8. The Coefficient of Correlation between I.Q.

and gain was .34. This is equivalent to a z-score of .3541[1] which is not significant at the 0.10 level, indicating that Intelligence Tests and the Developmental Tasks are not evaluating the same phases of intellectual development. Therefore, the hypothesis that there is no correlation between rate of attainment of formal operations and I.Q. cannot be rejected.

Developmental Level of Junior High School Learners

Table 12 shows the operational level of junior high school learners on the pretest and posttest. The determination of operational level was made by considering a score of 12 or below to indicate concrete operations, scores of 13 and 14 to be indicatibe of a transitional stage of development and a score of 15 or better to be indicative of formal operations.

Piaget indicates that learners should be moving into formal operations at the age of 11 years and thereafter. Since the individuals in the study were 13-16 years old, it is appropriate to expect them to be progressing into the stage of formal operations. In this study, 82 per cent of the learners were found to be concrete operational at the time of the pretest and 44 per cent of the learners were concrete operational at the time of the posttest. At the time of the pretest, 12 per cent were in a transitional stage and 16 per

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[1]Huntsberger, David V., Elements of Statistical Inference, Allyn and Bacon, Inc., 1961, p. 275.

cent were in a transitional stage at the time of the posttest; 6 per cent were formal operational at the time of the pretest and 40 per cent were formal operational at the time of the posttest.

This indicates that while learners were indeed making progress toward formal operations, they were not making the progress that might be expected from Piaget's findings. The conclusions can be drawn that either new norms need to be set up for our culture or that the educational experiences of the learners are not sufficient to allow maximum development. Perhaps both statements are true. More work needs to be done in this area.

Evaluation of the Major Hypothesis

The major hypothesis of this study was that students who are exposed to an inquiry type science course showed no significant gains in their ability to think logically when compared with students taking a traditional lecture-demonstration type course. The basis of determining a significant difference rests on the factors of the general patterns and trends of the data and the statistical tests of significance. It has been shown that for each group in the study there was a gain in achievement of the posttest over the pretest.

The experimental groups showed improvement over the control groups in eight of the nine cases; this difference was statistically significant in seven of the eight cases where improvement was shown. It was found that there was not a significant correlation between I.Q. and rate of gain of formal operational thought.

On the basis of the evaluation of these factors, the major hypothesis is rejected. On the basis of the evaluation of these data, there appears to be some factor operating which has caused a significant gain in attainment of formal operational thought. Since the only treatment difference in the control and experimental groups was the science course using lecture-demonstration methods or inquiry-centered methods, the inquiry centered science materials allowed the learners to achieve a greater gain in formal thinking than did the lecture-demonstration-type materials.

CHAPTER V

CONCLUSIONS, EDUCATIONAL IMPLICATIONS, AND SUGGESTIONS FOR FURTHER STUDY

Conclusions

The data[1] from this study support the following conclusions:

1. Junior high school students who are exposed to an inquiry-type science course show significant gains in their ability to think logically when compared with students taking a traditional, lecture-demonstration type science course.

2. Attainment of formal operations by junior high school students is not significantly related to sex.

3. Attainment of formal operations by junior high school students is not significantly related to I.Q.

4. Attainment of formal operations by eighth-grade learners is not significantly enhanced by the study of Introductory Physical Science materials.

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[1]These conclusions are valid if the assumption can be made that the individuals evaluated comprise a representative sample of the normal school population. If the sample is not representative, then the conclusions apply only to the group tested.

5. Attainment of formal operations by eighth-grade learners is not significantly enhanced by the study of Earth Science Curriculum Project materials.

6. Attainment of formal operations by eighth grade learners is significantly enhanced by the study of _Time, Space and Matter_ materials.

7. Attainment of formal operations by eighth-grade learners who take a science course using _Time, Space and Matter_ materials is significantly greater than that of eighth-grade learners who take a science course using Earth Science Curriculum Project materials.

8. Attainment of formal operations by eighth-grade learners who take a science course using _Time, Space and Matter_ materials is significantly greater than that of eighth-grade learners who take a science course using _Introductory Physical Science_ materials.

9. Attainment of formal operations by eighth-grade learners who take a science course using _Introductory Physical Science_ materials is significantly greater than that of eighth-grade learners who take a science course using Earth Science Curriculum Project materials.

10. Attainment of formal operations by ninth-grade learners is significantly enhanced by the study of Earth Science Curriculum Project materials.

11. Attainment of formal operations by ninth-grade learners is significantly enhanced by the study of _Introductory_

Physical Science materials.

12. Attainment of formal operations by ninth-grade learners who take a science course using Introductory Physical Science materials is significantly greater than that of ninth-grade learners who take a science course using Earth Science Curriculum Project materials.

13. Attainment of formal operations by ninth-grade learners who take a science course using Introductory Physical Science materials is significantly greater than that of eighth-grade learners who take a science course using Introductory Physical Science materials.

14. Attainment of formal operations by ninth-grade learners who take a science course using Earth Science Curriculum Project materials is significantly greater than that of eighth-grade learners who take a science course using Earth Science Curriculum project materials.

15. Of eighth and ninth-grade learners,82 per cent are concrete operational at the beginning of the school year.

16. Of eighth and ninth-grade learners studying traditional, lecture-demonstration type courses, 55 per cent are concrete operational at the end of the school year.

17. Of eighth and ninth-grade learners studying inquiry-type science courses, 39 per cent are concrete operational at the end of the school year.

18. Of eighth and ninth-grade learners, 6 per cent are formal operational at the beginning of the school year.

19. Of eighth and ninth-grade learners studying traditional, lecture-demonstration type courses, 25 per cent are formal operational at the end of the school year.

20. Of eighth and ninth-grade learners studying inquiry type science courses, 46 per cent are formal operational at the end of the school year.

Educational Implications

This study has shown that the educational activities that make up selected inquiry-type science curricula change the behavior of the learners in a manner that can be evaluated using developmental tasks suggested by Piaget and Inhelder. These tasks allow the evaluation of the ability to solve problems in a logical manner. The educational objective stated by the Educational Policies Commission, ". . . the development of the ability to think,"[2] has been achieved and measured at statistically significant levels.

It is very important to note that the curricula used in this research project effect significant gains in logical thinking ability at some grade levels and not at others. The *Time, Space and Matter* curriculum was shown to cause the greatest significant gains in the ability to solve problems at the eighth-grade level. In addition, the *Time, Space and* Matter was (at the eighth-grade level) shown to be significantly more effective in advancing operational level than

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[2]Educational Policies Commission, *op. cit.* p. 14.

either the Introductory Physical Science or Earth Science Curriculum Project curricula, and the Introductory Physical Science curriculum was shown to be significantly more effective than the Earth Science Curriculum Project materials. The Earth Science Curriculum Project and Introductory Physical Science materials were effective with ninth-grade learners and not with eighth-grade learners. At the ninth-grade level, however, the Introductory Physical Science curriculum was shown to be significantly more effective in changing operational level than were the Earth Science Curriculum materials. Both the Earth Science Curriculum Project and Introductory Physical Science curricula were found to be significantly more effective at the ninth-grade level than at the eighth-grade level.

On the basis of these findings, if a school system desired to offer earth and physical science to their eighth and ninth-grade learners, the most effective program would be to offer Time, Space and Matter at the eighth-grade level and Introductory Physical Science at the ninth-grade level.

Assuming that the learners evaluated constituted a normal sample, the finding that 82 per cent of eighth and ninth-grade learners are concrete operational at the beginning of the school year has broad implications for all subject-matter areas, not just science. The courses of study used by all disciplines need to be carefully evaluated so as to ascertain whether or not the activities prescribed for the learners are appropriate for their operational level.

It should not be necessary that the learner use interpropositional logic, i.e., formal operational thought, to successfully complete junior high school subjects.

Suggestions for Further Study

Findings in the data and educational implications resulting from them suggest a need for study in some areas. Two of these were indicated at appropriate places in the text and are summarized below:

1. Since the learners in this study did not make the progress toward the acquisition of formal operations that would be expected from Piaget's findings, either new norms need to be set up for our culture or the educational experiences of the learners are not sufficient to allow maximum development. Studies need to be conducted in both of these areas.

2. Both curricula now being used and proposed curricula should be evaluated to insure that the required activities are appropriate for the operational level of the learners at the grade level for which the curricula are recommended.

A further recommendation is that the curricula used in this research and other curricula should be studied so as to ascertain which elements of said curricula enhance the acquisition of formal operational thought.

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APPENDIX A

Conservation of Solid Amount[1]

The apparatus consists of two identical balls of clay and two beakers of water filled to the same level. After the shape of one of the clay pieces is changed, the subject is asked if each piece ofclay still contains the same amount. He is also asked how the water levels would change in the beakers if the clay pieces were placed in them. Solution of the problem involves the ability to handle differing proportions and the recognition of relevant variables.

If the subject reponds that one piece of clay contains more than the other after the form is changed, he is classified as being pre-operational, stage I, and no points are given. If he states that both pieces contain the same amount of clay, but that one would displace more water than the other, he is classified as being concrete operational, stage IIa and receives one point. If the subject says that after the change of form each piece has the same amount of clay and that the pieces would displace equal amounts of water, he is classified as concrete operational, stage IIb, and receives two points.

Conservation of Volume

The ability to conserve volume is acquired at the beginning of formal operations. The subject is presented

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[1]For a more complete description of the tasks, see Piaget and Inhelder, _op. cit._

with two metal cylinders of equal volume but differing weight and asked to predict which will displace the greater volume of water, or if each cylinder will displace the same amount of water. The successful solution of the task, realizing that the weight of the cylinder does not affect the volume it displaces, indicates that the learner has begun to move into formal operations.

If the subject responds that the metal cylinder will displace different amounts of water and cannot explain the results of the experiment, that the cylinders displace equal amounts of water, he is classified as concrete operational, stage Ia, and receives one point. If he predicts that the cylinders will displace equal amounts of water or explains the results of the experiment, he is classified as formal operational, stage IIIa and receives three points.

Reciprocal Implications

The equipment used resembles a billiard table with a plunger with which a ball can be aimed and shot. The object is to hit a marker placed on the table, using only one "bank." The subject is questioned about his observations, the principal interest being to what extent he induced that the object can be struck because the angle of incidence equals the angle of reflection.

If the subject realizes that the ball travels in straight lines forming an angle, rather than following a curved path, and makes general statements that the direction taken by the ball when it leaves the plunger is determined by the position of the plunger, he is classified as being concrete operational, stage Ia, and receives one point. If he can express the relationship between the position of the plunger and the direction the ball takes more accurately, he is classified as being concrete operational, stage IIb, and receives two points. If the subject expresses the equivalence of angles between the two directions, but thinks this may be a special case and not a general law, he is classified as being formal operational, stage IIIa, and receives three points. If he exhibits confidence in the generality of the law derived, i.e., that the angle of incidence equals the angle of reflection, he is classified as being formal operational, stage IIIb, and receives four points.

Elimination of Contradiction

The apparatus used is a water tank and a selection of objects, a nail, a cork, a rubber stopper, a wooden bead, and two bottles partially filled with water. The larger heavier bottle floats while the smaller, lighter one sinks. The subject is asked to classify the objects into two categories, those that will float and those that will sink. To solve the problem, the subject must resolve the apparent contradiction involving the two bottles and derive a law involving the weight and volume of the object compared to the weight and volume of the displaced water.

If the subject accurately classifies objects as sinking or floating objects, but offers multiple explanations relative to floating and sinking, he is classified as being concrete operational, stage IIa, and receives one point. If he states that there is a general law concerning floating and sinking but does not know what this law is, and also rejects ideas of absolute weight determining floating and sinking, he is classified as being concrete operational, stage IIb, and receives two points. If the subject hypothesizes the relationship between weight and volume, but does not verify this hypothesis, he is classified as formal operational, stage IIIa, and receives three points. If he relates the weight of the object to the weight of an equivalent volume of water and expresses confidence in the generality of the law, he is classified as being formal operational, stage IIIb, and receives four points.

Separation of Variables

The subject is presented with the opportunity to discover the variables effecting how much a rod will bend under varying conditions. The variables available for testing are length, material, cross-sectional area, shape and amount of weight attached to the end of the rod.

If the subject can categorize and classify the variable factors, but does not manipulate the relevant variables, he is classified as being concrete operational, stage IIa, and receives one point. If he exhibits a manipulative scheme, considering many variables, but does not verify the action of one variable, he is classified as being concrete operational, stage IIb and receives two points. If the subject attempts to verify his hypotheses and uses active searching behavior, in attempting to verify the action of the relevant variables, he is considered to be formal operational, stage IIIa, and receives three points. If he gives a rigorous proof of the action of one variable, he is considered to be formal operational, stage IIIb, and receives four points.

<u>Operations of Exclusion</u>

The apparatus used is a pendulum assembled to enable the length of the string and the weight of the bob to be varied. If the subject enumerates the variables in the pendulum system, but cannot separate their effects, he is classified as being concrete operational, stage IIa, and receives one point. If he can eliminate weight as a relevant variable, but cannot separate the other variables, he is considered to be concrete operational, stage IIb, and is given two points. If the subject forms an hypothesis about the effects of the variables, but does not test the effects of one variable at a time, he is considered to be formal operational, stage IIIa, and receives three points. If he can isolate, test, and order the effectiveness of all variables he is considered to be formal operational, stage IIIb, and receives four points.

APPENDIX B

The researcher gathered the data shown in Appendix B, Table 1, to validate the tasks used in the study. The individuals used in this sample are freshman law students at the Oklahoma City University Law School. This sample was chosen because an examination of the types of activities which law students must function with in order to succeed demonstrate that they must use formal thought. They, however, have not studied science extensively. The success they have with the Piagetian tasks is because they are formal operational and not because they have studied the concepts involved. Since 18 of the 22 subjects were determined to be formal operational and two to be in a transitional stage between concrete and formal operations, we can safely assume that the selected tasks do indeed evaluate logical thinking ability.

TABLE 13

CLASSIFICATION OF LEVEL OF THOUGHT OF TWENTY-TWO LAW SCHOOL FRESHMEN USING FOUR PIAGETIAN TASKS

Student Number	Cons. of Volume	Reciprocal Implication	Elimination of Contradiction	Exclusion	Level of Thought
1.	2	4	4	4	Formal
2.	2	3	3	2	Formal
3.	2	2	4	4	Formal
4.	2	4	4	3	Formal
5.	2	4	4	4	Formal
6.	2	4	3	4	Formal
7.	2	2	3	1	?
8.	2	2	3	3	Formal
9.	2	4	4	1	Formal
10.	2	2	4	2	?
11.	2	4	4	3	Formal
12.	2	3	4	4	Formal
13.	2	2	2	1	Concrete
14.	2	2	4	3	Formal
15.	1	2	3	3	Formal
16.	1	2	2	1	Concrete
17.	0	4	4	2	Formal
18.	2	3	4	4	Formal
19.	1	4	3	2	Formal
20.	1	2	3	4	Formal
21.	2	3	3	1	Formal
22.	2	4	4	3	Formal

APPENDIX C

Form Used for Pretest

Conservation of Solid Amount (Clay) ____________

Conservation of Volume ____________

Reciprocal Implication (Pool) ____________

Elimination of Contradictions (Float-Sink) ____________

Separation of Variables ____________

Exclusion (Pendulum) ____________

Name____________________________ Teacher______________________

School__________________________ Hour_________________________

Tester______________________________

Form Used for Posttest

Name______________________ Teacher______________________

Date of Birth______________________ Hour______________________

School______________________ Curriculum______________________

Grade______________________ Other______________________

Conservation of Solid Amount (Clay) ____________

Conservation of Volume ____________

Reciprocal Implication (Pool) ____________

Elimination of Contradiction (Float-Sink) ____________

Separation of Variables ____________

Exclusion (Pendulum) ____________

APPENDIX D

Explanation of Statistical Methods Used

Since the groups were not matched, and the pretest scores were not identical, an analysis of co-variance was performed which statistically eliminates differences between groups. The following equations were used:

$$\Sigma y^2\text{Total} = \Sigma Y^2 - \frac{(\Sigma Y)^2}{N}$$

$$\Sigma y^2\text{Treatment} = \frac{(\Sigma Y_1)^2}{k_1} + \frac{(\Sigma Y_2)^2}{k_2} - \frac{(\Sigma Y)^2}{N}$$

$$\Sigma y^2\text{Error Within} = \Sigma y^2_{\text{Total}} - \Sigma y^2_{\text{Treatment}}$$

x^2 values were calculated by substituting the corresponding values of X in the equation above.

$$\Sigma xy_{\text{Total}} = \Sigma XY - \frac{\Sigma X \Sigma Y}{N}$$

$$\Sigma xy_{\text{Treatment}} = \frac{\Sigma X_1 \Sigma Y_1}{k_1} + \frac{\Sigma X_2 \Sigma Y_2}{k_1} - \frac{\Sigma X \Sigma Y}{N}$$

$$\Sigma xy_{\text{Error Within}} = \Sigma xy_{\text{Total}} - \Sigma xy_{\text{Treatment}}$$

$$b = \frac{\Sigma xy}{\Sigma x^2}$$

$$SSresidual = \Sigma y^2 - b(\Sigma xy) \quad \text{(Using Total Figures)}$$

$$SSerror = \Sigma y^2 - b(\Sigma xy) \quad \text{(Using Error Within Figures)}$$

Analysis of Covariance Table

Source	df	SS	MS
Treatment			
Error Within			
Within + Treatment			

To obtain the Treatment figures, subtract the Error figures from the residual figures.

To calculate df (degrees of freedom) use N as a base and subtract one to allow for bias in the data, one for control, and one for the main effect.

To calculate the MS (Mean Square), divide SS (Sum of Squares) by the number of degrees of freedom.

To calculate the F-value, divide the $MS_{Treatment}$ by the $MS_{Error\ Within}$ and consult an F-table using the proper number of degrees of freedom and level of significance.

$$F_{(df_{Treatment}, df_{Error\ Within})} = \frac{MS_{Treatment}}{MS_{Error}}$$

The letters used in the formulas represent the following values:

X_1 = the score of the control group on the pretest.

Y_1 = the score of the control group on the posttest.

X_2 = the scores of the experimental group on the pretest.

Y_2 = the scores of the experimental group on the posttest.

X = the scores of the control group plus the experimental group on the pretest.

Y = the scores of the control group plus the experimental group on the posttest.

k_1 = the number of subjects in the control group.

k_2 = the number of subjects in the experimental group.

N = the total number of subjects.

The following formula was used to compare the rate of attainment of formal operations to I.Q.:

$$r = \sqrt{\frac{\left[N\Sigma XY - (\Sigma X)\ (\Sigma Y)\right]^2}{\left[N\Sigma X^2 - (\Sigma Y)^2\right]\left[N\Sigma Y^2 - (\Sigma Y)^2\right]}}$$

X = the score on the posttest minus the score of the pretest.

Y = the I.Q. score.

N = the number of individuals involved in the study for whom I.Q. scores were available.