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THE UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

THE INFLUENCE OF INQUIRY LEARNING ON INTELLECTUAL DEVELOPMENT, ACHIEVEMENT, AND IQ

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

BY

EDMUND A. MAREK

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THE INFLUENCE OF INQUIRY LEARNING ON INTELLECTUAL DEVELOPMENT, ACHIEVEMENT, AND IQ

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THE INFLUENCE OF INQUIRY LEARNING ON INTELLECTUAL DEVELOPMENT, ACHIEVEMENT, AND IQ

CHAPTER I

INTRODUCTION

Background of the Problem

The intervention of extra-school influence upon curriculum began in the late 1950's. These influences introduced to United States education many new factors that had previously been ignored. One of those factors was the involvement of the professional scientist in curriculum development. That professionals' intervention was to insure that the accuracy of the discipline's structure would be built into new and revised science curricula.

The scientist-advised curricula had a large degree of success. All of those curricula, for the junior and senior high school, ignored the consideration of the level of intellectual development of the secondary school students. Research data suggests that many of the students studying these courses could not profit from them because of their

states of intellectual development.[1,2] As Lawrence Kohlberg and Carol Gilligan explain: "Clearly the new curricula assumed formal operational thought rather than attempting to develop it."[3]

Of all the theories of intellectual development that exist, the one that has probably generated the most activity, excitement, controversy, and research in the last ten years is the one attributed to the Swiss biologist-psychologist-epistemologist Jean Piaget. From this activity and research greater understanding of cognitive development and logical thinking have resulted but left with incomplete answers are such basic questions as: 1) Are Piagetian levels of intellectual development, intelligence quotient, and achievement interrelated? and 2) Can intellectual development, IQ, and achievement be enhanced by the inquiry teaching methodology? It is the intention of this study to provide evidence to enable those questions to be answered.

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[1]Anton E. Lawson and John W. Renner, "Relationships of Science Subject Matter and Developmental Levels of Learners," Journal of Research in Science Teaching, 1975, vol. 12, No. 4, pp. 347-358.

[2]John W. Renner and Don G. Stafford, Teaching Science in the Secondary Schools, (New York: Harper and Row Publishers, 1972), pp. 291-296.

[3]Lawrence Kohlberg and Carol Gilligan, "The Adolescent as a Philosopher," Journal of the American Academy of Arts and Science, Fall, 1975, pp. 1051-1086.

Statement of the Problem

What are the relationships among intellectual development, intelligence quotient, and achievement of high school biology students who experience the inquiry teaching methodology?

Definition of Terms

In this investigation are terms used in a specific way. Those terms and their meanings are given in this section.

Intellectual Development--Four phases of cognitive growth, described by Paiget,[4] the human organism can pass through.

Action--A system of coordinated movements functioning for a result or an intention.[5]

Operations--Piaget defines an operation as a means for mentally transforming data about the real world so that they can be organized and used selectively in the solutions of problems.[6]

Concrete Operational--Operational groupings of thought concerning objects that can be manipulated or known

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[4]Jean Piaget, The Psychology of Intelligence (London: Lowe and Brydone Limited, 1971), pp. 119-155.

[5]_____, The Child and Reality (New York: Grossman Publishers, 1972), p. 63.

[6]Bärbel Inhelder and Jean Piaget, The Growth of Logical Thinking from Childhood to Adolescence (New York: Basic Books, Inc., 1958), p. xiii.

through the senses. Thought is reversible, transformations are sensed, and many aspects of a situation are focused on simultaneously.[7]

Formal Operational--The phase of cognitive growth represented by propositional logic or hypothetical-deductive reasoning.[8]

Intelligence Quotient--A chronological age to mental age measure of the learned ability to form relationships with verbal and symbolic concepts.

Achievement--Learned conceptual and factual knowledge and mastery of inquiry skills.

Psychometric--A measure of learned abilities. IQ and achievement are examples of this type of intelligence assessment.

Inquiry--Analyzing problems, developing hypotheses, searching the literature, designing experiments to test the hypotheses, executing those experiments, interpreting the results, and inferring future results. (Inquiry skills are qualified by this definition.)

Related Research

The survey of the literature presents research related to the variables stated in the problem. A discussion of intellectual development and IQ is presented first followed

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[7]Ibid., pp. 272-278.

[8]Ibid., pp. 307-333.

by comparisons of intellectual development and achievement. Concluding the survey are studies of the inquiry teaching methodology versus intelligence.

DeVries reviewed the literature and found contradictory results concerning the relationship between intelligence quotient and Piagetian assessments of intellectual development.[9] Studies of several researchers--Kohlberg and Devries; Stephens, McLaughlin, Miller, and Glass; Stephens; and Hathaway--indicated, generally, no relationship between IQ and Piagetian methods of assessing intellectual development. Conversely, studies conducted by Kohlberg and Goodnow and Benthon showed that high-IQ children out performed average-IQ children. Research of Inhelder and research of Stephens showed average-IQ children out performed low-IQ children. In DeVries' study to resolve this conflict, it was concluded that psychometric mental age, determined from the Stanford-Binet Intelligence Scale, is not a reliable predictor of Piagetian stage development except in the general sense that brighter students become concrete operational sooner.[10]

The hypothesis is advanced that Piagetian and psychometric methods assess two different portions of intelligence.

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[9]Rheta DeVries, "Performance on Piaget-Type Tasks of High-IQ, Average-IQ, and Low-IQ Children," Paper presented at the annual meeting of the Society for Research in Child Development, Philadelphia, Pennsylvania, March 29 through April 1, 1973.

[10]Ibid.

Piagetian assessments of intelligence depict the level of cognitive development or reasoning level of the learner.

> . . . IQ tests do not measure innate intellectual capacity, but rather a group of learned skills that can be taught in the classroom or in the home. Specifically, they measure the learned ability to form relationships with verbal and symbolic concept.[11]

Sayre and Ball found at certain grade levels students demonstrating formal operational logic received higher grades than nonformal operational students and subsequently summarized that the lower grades of the nonformal operational students may be due, partially, to their cognitive developmental stage.[12] Lawson and Renner found that concrete operational subjects could understand approximately thirty percent of concrete operational concepts and little or no formal operational concepts.[13]

Research found that not until the students became formal operational did they begin to demonstrate understanding in formal operational concepts. Therefore, formal operational students show understanding in both concrete and formal concepts while concrete operational students are able to develop an understanding of concrete concepts.[14]

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[11]Arthur Whimbey, "Something Better Than Binet?," Saturday Review/World, 1974 vol. 1, No. 19, p. 50.

[12]Steve Sayre and Daniel W. Ball, "Piagetian Cognitive Development and Achievement in Science," Journal of Research in Science Teaching, 1975, vol. 12, No. 2, pp. 172-173.

[13]Lawson and Renner, "Relationships of Science Subject Matter and Developmental Levels of Learners," p. 347.

[14]Ibid., pp. 355-356.

Research conducted by Stafford and Renner showed that more first grade children who were taught with an inquiry science program--Science Curriculum Improvement Study--entered into the concrete operational stage, as measured by the Piagetian conservation tasks, than did the control students.[15] The control students studied a conventional textbook science program. In addition to this study with elementary school subjects, Friot showed eighth- and ninth-grade learners, who were exposed to an inquiry-type science program, demonstrated significant gain in their ability to think logically.[16] The comparisons were with learners exposed to a traditional lecture-demonstration type science course. Also Friot discovered no significance between IQ and attainment of formal operations by junior high school students. In another study of inquiry methodology, McKinnon and Renner found that college freshmen acquired formal operational thought patterns when enrolled in a course which used inquiry techniques.[17]

None of the studies just cited addresses itself to the question: What are the relationships among intellectual

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[15]Don G. Stafford and John W. Renner, "SCIS Helps the First Grader to Use Logic in Problem Solving," School Science and Mathematics, Feb., 1971, pp. 159-164.

[16]Faith E. Friot, "Curriculum Experiences and Movement from Concrete-Operational Thought," in John W. Renner et.al., Research, Teaching, and Learning with the Piaget Model (Norman: University of Oklahoma Press, 1976), pp. 79-89.

[17]Joe W. McKinnon and John W. Renner, "Are Colleges Concerned with Intellectual Development," American Journal of Physics, 1971, vol. 39, No. 9, pp. 1050-1052.

development, intelligence quotient, and achievement of high school biology students who experience the inquiry teaching methodology?

Theoretical Framework

The theoretical framework for this study is based primarily on Piaget's paradigm of intellectual development.[18] As succinctly stated by Renner and Stafford, "the development which a learner undergoes explains what he can learn rather than the learning explaining and accounting for his development."[19] Following are delimitations of the four developmental periods:

1. The sensori-motor period is when the child learns to coordinate perceptual and motor functions and to utilize certain elementary behavior patterns for dealing with external objects. He comes to know that objects exist even when outside his perceptual field and coordinates their parts into a whole recognizable from different perspectives.[20]

2. The preoperational period extends from the beginning of organized symbolic behavior-language in particular-until about seven years. The child comes to represent the external world through the medium of symbols, but he does so primarily

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[18] Inhelder and Piaget, The Growth of Logical Thinking from Childhood to Adolescence.

[19] Renner and Stafford, Teaching Science in the Secondary School, pp. 64-65.

[20] Inhelder and Piaget, The Growth of Logical Thinking from Childhood to Adolescence, Translators Introduction, p. xi.

by generalization from a motivational model--e.g., he believes that the sun moves because "God pushes it" and that the stars, like himself, have to go to bed. He is much less able to separate his goals from the means for achieving them than the operational level child.[21] The preoperational child is egocentric, unable to reverse thought, cannot see states in a transformation, reasons transductively, and lacks conservation reasoning.

3. Concrete operational children focus on several aspects of a situation simultaneously, are sensitive to transformations, and can reverse the direction of their thinking.[22] Children at this developmental stage operate on objects that can be known through the senses and exhibit conservation reasoning.[23]

4. The formal operational period is represented by hypothetical-deductive reasoning or propositional logic. A formal operational thinker can think about the consequence and implications of his own thinking.[24]

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[21]Ibid., p. xii.

[22]Herbert Ginsburg and Sylvia Opper, Piaget's Theory of Intellectual Development (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1969), p. 168.

[23]John L. Phillips, Jr., The Origins of Intellect: Piaget's Theory (San Francisco: W. H. Freeman and Company, 1975), p. 117.

[24]John W. Renner, Robert Bibens, and Gene Shepherd, Guiding Learning in the Secondary School (New York: Harper and Row Publishers, Inc., 1972), p. 107.

Learning, according to Piaget, is knowing something by acting upon it and/or interacting with it.[25] The mode of learning considered in this study is inquiry. Renner defines inquiry as exploration, invention, and discovery.[26] The learner collects data through observation, is introduced to the concept from these data (i.e. invention), and subsequently applies the concept (i.e. discovery). Friot, McKinnon, and Stafford have shown the inquiry teaching methodology to enhance cognitive development.[27,28,29]

From this theoretical framework and related research mentioned previously, the following variables have been selected for study: intellectual development, IQ, achievement, and inquiry.

General Hypothesis

Learning by the inquiry methodology does affect intellectual development, intelligence quotient, and achievement in content and inquiry skills.

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[25]Renner and Stafford, Teaching Science in the Secondary School, p. 65.

[26]Ibid. Chapter 4.

[27]Friot, "Curriculum Experiences and Movement from Concrete-Operational Thought," pp. 79-90.

[28]McKinnon and Renner, "Are Colleges Concerned with Intellectual Development," pp. 1050-1051.

[29]Stafford and Renner, "SCIS Helps the First Grader to Use Logic in Problem Solving," pp. 159-164.

Specific Hypotheses

Hypothesis I: Subjects taught by the inquiry methodology experience a significant increase in intellectual development.

Hypothesis II: Subjects taught by the inquiry methodology experience a significant increase in intelligence quotient.

Hypothesis III: Subjects taught by the inquiry methodology experience a significant increase in content achievement.

Hypothesis IV: Subjects taught by the inquiry methodology experience a significant increase in inquiry skills achievement.

Hypothesis V: There is a relationship among intellectual development, IQ, and achievement in high school biology students.

CHAPTER II

TREATMENT, DESIGN, AND INSTRUMENTATION

Description of the Experimental Treatment

In order to gather data to answer the questions discussed in Chapter I, a student experimental group was required. Using a table of random digits[1] a sample of 100 subjects from five biology sections at West Mid High School in Norman, Oklahoma, was selected. The experimental group was taught using the inquiry methodology during the 1976-1977 school year. Ninety-two of the subjects completed the study.

The treatment was implemented using the Inquiry Role Approach[2] (IRA) program which was designed and evaluated by the Mid-continent Regional Educational Laboratories. IRA was designed to develop inquiry and social skills, understanding of biology content, and attitudinal qualities. Specific examples of these goals include: 1) inquiry skills--formulating problems and hypotheses, using science literature,

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[1]Edward W. Minium, Statistical Reasoning in Psychology and Education (New York: John Wiley and Sons, Inc., 1970), pp. 454-455.

[2]Mid-continent Regional Educational Laboratory, Inquiry Role Approach (Morristown, New Jersey: Silver Burdett Company, 1974).

designing experiments, interpreting data, and synthesizing new knowledge; 2) social skills--coordination and communication with classmates, social interaction, and role performance; 3) content--knowledge of biology principles and concept in ecology, bioenergetics, cell biology, and scientific research methodology; 4) attitudinal qualities--curiosity, openness, satisfaction, and responsibility.

Approximately one-third of the class time was devoted to working in three-or four-member groups. The class work (IRA activities) is explained in the next paragraph. To facilitate this small group performance, each team member had a portion of the group's responsibilities. These responsibilities are described by structured roles[3] the students fulfilled. A description of the roles is given in Appendix A. Individual preparation of the assignments preceded the group work. The students read the assignment and prepared any materials for the team dictated by their roles. During the course of the year approximately one-third of class time was devoted to this individual preparation. The remaining one-third of the time the students spent participating in class discussions of the team work.

The IRA program consists of three types of classroom activities.

1. Laboratory Investigations: The manual which guided the teams in performing experiments is called Laboratory

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[3]Ibid., Activity 6, pp. 15-19.

Investigations in Biology.[4] Twenty-six of the sixty-four investigations included were completed as part of the IRA program.

2. Inquiry Guides:[5] An inquiry guide is a paper-and-pencil problem-solving activity in which the students are given a series of biological statements; for example, "Water and energy are the principal limiting factors to the life of an ecosystem." Their task is to determine if the statement is acceptable or unacceptable and to support their positions with evidence from textual and laboratory references. After the inquiry guide was completed individually, team discussions took place. Ten inquiry guides were completed during the experimental treatment.

3. Laboratory Explorations in Biology (LEIB):[6] The LEIBs differ greatly from traditional laboratory experiments. During the LEIB each team chose its own problem of study which was developed from concepts introduced in the preceding inquiry guides and laboratory investigations. The teams then formulated an hypothesis for the problem and designed experiments to prove or disprove that hypothesis. In addition the teams researched related literature, gathered and interpreted

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[4]Ann F. Benson and Edna R. Green, Laboratory Investigations in Biology (Morristown, New Jersey: Silver Burdett Company, 1974).

[5]Mid-continent Regional Educational Laboratory, Inquiry Role Approach, Activity 8, pp. 24-31.

[6]Ibid., Activity 19, pp. 63-68.

data from the experiments, and finally applied the knowledge to related concepts. The last step of the LEIB is a synthesis, in other words, the data and conclusions of the research are applied to other biological situations. Teams usually spend the entire class period for a full month pursuing a LEIB, after which they report to the class.

The LEIB is the culminating activity and it is preceded by completing related laboratory investigations, and inquiry guides. This sequence of activities constitutes a cycle--laboratory investigations, inquiry guides, and the LEIB. Three of those cycles were completed during the experimental treatment. These cycles encompassed ecology, bioenergetics, plus a sampling of many other areas selected by the teams for the third cycle. Included among the selected areas were topics from microbiology, nutrition, and environmental health.

Design of Study

A pretest-posttest design of four parameters (cognitive development, content achievement, inquiry skills achievement, and IQ) was employed to analyze the affect of the inquiry treatment and to see if any relationships existed among these four variables. The instruments used to measure these variables are listed below. Two of the variables, content achievement and inquiry skills achievement, were compared to a control group.

The control group used in this study was part of the IRA field test during the 1972-1973 school year.[7] Four hundred and sixty-five tenth grade subjects from suburban midwest and west coast high schools constituted the control group. This group was taught by teachers with no IRA materials nor any IRA training. A traditional lecture-laboratory-demonstration methodology was taught from Biological Science--An Inquiry into Life.[8]

Different teachers and teacher attitude are two variables necessary to control or eliminate in the experimental treatment. The teacher variable refers to a situation where different teachers are teaching the experimental methodology. The teacher attitude variable really controls how that person would approach the teaching act. A traditionally oriented teacher, for example, could negatively affect the inquiry teaching methodology and an inquiry oriented teacher could negatively affect the traditional teaching methodology. The researcher and his advisor believed that a teacher's attitude, professional training, and personal biases would affect the experimental treatment and subsequently the data. To eliminate the teacher variable and teacher attitude variable explained previously one teacher taught the experimental group

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[7]Mid-continent Regional Educational Laboratory, "Inquiry Role Approach Field Test Report 1972-73," unpublished report.

[8]Biological Science Curriculum Study, Biological Science--An Inquiry into Life (New York: Harcourt, Brace, and World, Inc., 1968).

(refer to the previous section for a description of the treatment).

Since control group data were available (IRA field test report of 1972-1973) the control-experimental group design was employed to circumvent the extraneous teacher variables. The variables of teacher and teacher attitude were minimized in the control group because the teachers of the control and test group of the 1972-1973 IRA field test were matched in terms of textbook used, experience in teaching, and general teaching approach. These control group data therefore had validity when comparing content achievement and inquiry skills achievement to the experimental group of the present research because of this similar teacher variable control, the identical methodologies under examination, and similar instructional materials of both studies.

Content achievement of the control group was measured by the Comprehensive Final Examination,[9] an instrument developed by the Biological Sciences Curriculum Study (BSCS). BSCS also produced the Resource Book of Test Items for Biological Science--An Inquiry into Life.[10] This book and the IRA program are the sources of the questions used to measure content

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[9]Biological Sciences Curriculum Study, Comprehensive Final Examination Form J (New York: Psychological Corporation, 1965).

[10]Biological Sciences Curriculum Study, Resource Book of Test Items for Biological Science: An Inquiry into Life (Boulder, Colorado: Educational Programs Improvement Corporation, 1971).

achievement of the experimental group in the present research. That achievement was measured by the "Biology Content Examination," a teacher-assembled and teacher-made multiple choice test. The control and experimental groups' content instruments therefore have the BSCS as a common source of test questions.

Inquiry skills achievement of the control group and the experimental group was measured with the "Explorations in Biology" (EIB) test.[11] The EIB was developed and evaluated by Mid-continent Regional Educational Laboratories and assesses inquiry skills attainment.

Inhelder and Piaget[12] developed numerous tasks for determining cognitive development. From these tasks four were selected to measure cognitive development in the experimental group only. Included were Conservation of Volume, Combinations of Colorless Liquid Chemicals, Separation of Variables, and Ratios.[13] These four Piagetian tasks were selected because they elicit representative and comprehensive measures of the cognitive stages of the subjects.

Intelligence quotient, also determined in the experimental group only, was measured with the Short Form Test of

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[11]Mid-continent Regional Educational Laboratories, Inquiry Role Approach, Appendix, p. 113.

[12]Inhelder and Piaget, The Growth of Logical Thinking from Childhood to Adolescence, Part I and Part II.

[13]John W. Renner, et.al., Interview Protocols for Tasks to Determine Levels of Thought (Norman, Oklahoma: University of Oklahoma Press, 1976).

Academic Aptitude Level Five[14] (SFTAA). The SFTAA level five was obtained from the University of Oklahoma Testing Service and scored by the same organization.

The resultant data produced from administering the four Piagetian tasks, the content examinations, the EIB, and the SFTAA were examined in two phases. The first phase consists of two subdivisions: 1) an analysis of variance in pre- and posttest scores of the experimental group in cognitive development, content achievement, inquiry skills achievement, and IQ, and 2) a comparison of the control group to the experimental group in content achievement and inquiry skills achievement. The second phase of the data analysis is a correlational examination of the experimental group's data from the tests listed above. In addition to these parameters, the sex and age of the subjects are included.

Instrumentation

Overview

There are ten variables in this study: sex, age, pre- and post-cognitive development, pre- and post-content achievement, pre- and post-inquiry skills achievement, and pre- and post-IQ. The data were examined in two phases. First, an analysis of variance between pretest and posttest scores of

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

cognitive development, content achievement, inquiry skills achievement and IQ to determine the degree of significance of the effect that occurred due to the inquiry treatment. Second, a correlation matrix was computed to ascertain relationships among the ten variables previously listed.

The following sections are devoted to 1) a description of the instruments used to analyze the dependent variables, 2) a consideration of the types of possible decision errors and their consequences, and 3) a discussion of the data analysis tools.

Description of the Instruments

Cognitive development of the experimental group was measured with four Piagetian tasks: Conservation of Volume, Combinations of Colorless Liquid Chemicals, Separation of Variables, and Ratios. A team of experienced examiners from the University of Oklahoma administered the tasks using the interviewing protocols developed by the Cognitive Analysis Project.[15] According to their responses during the interview, the subjects' level of intellectual development were scored as concrete (IIA or IIB) or formal (IIIA or IIIB) for each task. Total numerical scores were then determined by adding each task's score (IIA = 1, IIB = 2, IIIA = 3, and IIIB = 4). Appendix B contains the protocols used in interviews.

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[15]Renner et.al., Interviewing Protocols for Tasks to Determine Levels of Thought, pp. 3-10.

Achievement in content, which measured the amount of subject matter learned and retained, was determined in the experimental group by the teacher-assembled-teacher-made multiple choice test. The test questions were obtained from the BSCS Resource Book of Test Items and the IRA program. The investigator and his advisor made an a priori face validity judgement of this 142 item content test. The test had evolved from four years of compilation and classroom usage. The reliability of the content test was determined in the spring, 1976, by administering it to seventy-one tenth grade students drawn from the same population as the experimental group in this study. The 1976 subjects were from the same school, teacher, and instructional program as the experimental group of the following year. Using the 1976 data, the reliability was calculated and 102 of the 142 items proved to be a reliable ($r = 0.73$) content achievement instrument. These items (titled "Biology Content Examination") were used to measure content achievement of the experimental group and are located in Appendix C. Items one through fifty-nine (Theme I) reflected a sample of the subject matter presented in the first cycle. Items sixty through 102 (Theme II) reflected the second and third cycles' content. Inter-item consistency of each theme was determined with the Kuder-Richardson equation 20.[16] The equation is as follows:

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[16]J. P. Guilford, Fundamental Statistics in Psychology and Education (New York: McGraw-Hill Book Company, 1965), p. 459.

$$r_{tt} = \left(\frac{n}{n-1}\right)\left(\frac{\sigma^2_t - \Sigma pq}{\sigma^2_t}\right)$$

where n = the number of items in the test

σ^2 = the variance

p = the proportion passing (or responding in some specific manner) an item from Theme t.

q = 1 - p

Reliability for Theme I was 0.96 and for Theme II 0.86.

Pearson's product-moment formula was then applied to determine the parallel forms correlation between the two parts of the instrument.[17] The formula is as follows:

$$r_{xy} = \frac{\Sigma xy}{N\sigma_x\sigma_y}$$

where x = deviation of any X score from the mean of test X

y = deviation of the corresponding Y score from the mean in test Y

σ = standard deviation

The reliability for the combined themes (r = 0.73) was reported previously.

Achievement of inquiry skills is an index measuring the degree to which inquiry skills have been mastered. The

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[17]Ibid., p. 95.

instrument to assess inquiry skills was the "Explorations in Biology" test and is found in Appendix D. High pretest scores on any test allow less opportunity for increase on posttest scores. This situation occurred in the experimental group and is discussed in Chapter IV.

IQ was measured by the Short Form Test of Academic Aptitude level five. The SFTAA level five, derived from the California Test of Mental Maturity Series, is found in Appendix E.

Decision Errors and Consequences

Several criteria were considered in establishing level of significance. Two kinds of Type II errors can be committed in this research. These are--1) accepting no effect on intellectual development, achievement, and IQ from an inquiry methodology when in fact there was an affect and 2) accepting no relationship among intellectual development, achievement, and IQ when in fact there is a relationship. Committing either of these Type II errors could mean recommendations and implementation of inappropriate content and methodology. Such a decision is educationally deleterious. Related research[18,19,20] of teaching methodologies documents

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[18]Stafford and Renner, "SCIS Helps the First Grader to Use Logic in Problem Solving," pp. 159-164.

[19]Friot, "Curriculum Experiences and Movement from Concrete-Operational Thought," pp. 79-89.

[20]McKinnon and Renner, "Are Colleges Concerned with Intellectual Development," pp. 1050-1051.

traditional teaching methodologies to be significantly less effective on intellectual development than the inquiry teaching methodology further exemplifying the seriousness of a Type II error in this research. There are two Type I errors that can be committed--1) accepting that the inquiry methodology had an effect on intellectual development, achievement, and IQ when in fact there was none and 2) accepting a relationship among intellectual development, achievement, and IQ when in fact there is none. Committing either of these decision errors would be less serious resulting only in monetary waste from implementing unnecessary changes in curricula, presuming any changes would be made at all. It is the judgement of the researcher that a Type II error in this research is exceedingly more harmful to education.

Minium states that, ". . . unthinking conservatism in minimizing α will have an unnecessarily adverse influence on β."[21] With α set very low then there exists a greater chance of committing a Type II error which, the reader is reminded, is most important to avoid in this research. It is the decision of the researcher, therefore, to report rather than select a level of significance.

Data Analysis Tools

In the first phase of data analysis, cognitive development, content achievement, inquiry skills achievement, and IQ

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[21]Minium, Statistical Reasoning in Psychology and Education, p. 336.

indicies of the experimental group were tested for significance between pretest and posttest results using a matched pairs t-test.[22] If any significant change occurred due to the treatment, this statistical tool would reflect that.[23] The appropriate equation is:

$$t = \frac{M_d}{\sqrt{\frac{\Sigma x_d^2}{N(N-1)}}}$$

where M_d = the mean of the N difference of paired observations

x_d = the deviation of a difference from the mean of the difference

N = the number of subjects in the sample

A comparison between the control group and experimental group with respect to content achievement and inquiry skills achievement is made in the following chapter. Using bar graphs, comparisons of the mean percentage scores of the control group and experimental group in content achievement and also inquiry skills achievement are shown. This graphic analysis rather than inferential statistics was employed because the testing instruments were analogous though not

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[22]Guilford, Fundamental Statistics in Psychology and Education, p. 184.

[23]Minium, Statistical Reasoning in Psychology and Education, p. 353.

identical.

In the second phase of the data analysis, a 10 x 10 correlation matrix was produced which included sex, age, pre- and post-cognitive development, pre- and post-content achievement, pre- and post-inquiry skills achievement, and pre- and post-IQ indicies. Sums, means, and standard deviations were calculated. Statistically significant correlations between any two variables were confirmed by values greater than ±0.267 at at least the 0.01 alpha level with the df at 90.[24] This value would mean that there is a relationship between the two variables under examination at that significance level. The actual significance levels are reported with the data presentation, analysis, and interpretations.

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[24]Ibid., p. 446.

CHAPTER III

PRESENTATION OF THE DATA

The data in this investigation were collected to provide evidence to answer the questions: 1) How are student intellectual development, content achievement, inquiry skills achievement, and IQ affected by the inquiry teaching methodology? and 2) How are student intellectual development, content achievement, inquiry skills achievement, and IQ interrelated? The data are presented in two sections corresponding to these questions.

Section A deals with the effect of the inquiry treatment. This section presents the raw data, pretest and posttest means of the experimental group, t-test values of the experimental group, and pretest and posttest means of the control and experimental group with respect to content and inquiry skills achievement. Section B presents a correlation matrix which deals with the interrelationships of the ten dependent variables.

Section A

The raw data are presented in Table 3-1. The columns labeled 'pre' are the pretest scores and the columns labeled 'post' are the posttest scores.

TABLE 3-1

RAW DATA FOR EXPERIMENTAL GROUP

Ss No.	Sex	Age in Months	Cognitive Development		Content Achievement		Inquiry Skills Achievement		Intelligence Quotient	
			Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	M	180	10	12	46	47	33	40	105	98
2	M	191	8	9	38	42	19	29	92	95
3	F	189	12	12	40	71	37	42	111	116
4	F	177	5	9	53	62	41	37	102	110
5	F	181	9	11	42	52	31	53	98	102
6	M	189	12	12	51	70	37	27	103	108
7	M	188	7	8	63	80	47	43	113	120
8	F	187	9	8	48	62	32	46	101	102
9	F	186	7	10	45	50	38	38	97	103
10	M	185	11	13	63	76	39	38	126	135
11	F	189	6	9	48	42	35	32	106	90
12	F	184	11	11	50	72	37	41	123	135
13	F	180	7	9	46	64	44	39	114	121
14	F	182	7	10	45	61	30	45	105	105
15	M	188	12	15	42	62	23	38	92	102
16	M	184	12	13	46	51	38	43	98	98
17	F	189	5	8	47	51	40	44	95	97
18	M	187	11	9	48	66	40	45	108	104
19	F	189	11	11	53	81	45	50	130	111
20	F	183	10	10	58	74	45	40	110	113
21	F	187	13	13	48	84	40	41	144	123
22	F	191	7	9	44	54	32	45	95	95
23	M	192	9	8	54	63	32	35	101	102
24	F	189	7	8	38	40	31	41	103	100
25	F	191	9	11	40	63	26	41	92	102
26	F	191	5	6	44	47	29	38	82	90
27	F	189	8	9	53	76	48	52	115	125
28	M	186	9	11	47	63	40	43	121	119
29	F	179	8	12	51	72	38	33	113	121
30	M	182	12	15	62	76	46	50	133	127
31	M	182	10	7	49	57	26	31	105	101
32	F	184	8	13	23	52	13	35	103	116
33	M	182	10	12	52	65	39	38	108	106
34	F	180	6	8	46	51	40	41	101	107
35	F	181	9	9	25	69	26	47	118	136
36	F	184	6	9	39	70	32	43	108	113
37	M	190	8	9	34	44	34	41	91	91
38	M	180	12	12	33	83	39	47	107	111
39	F	185	12	10	49	40	42	40	105	102
40	M	191	12	11	75	84	46	47	120	124
41	M	190	9	10	48	60	43	37	106	107
42	F	185	11	10	36	48	24	36	99	102
43	F	187	7	6	37	40	22	24	84	80
44	F	189	7	9	47	73	32	41	110	110

TABLE 3-1 CONTINUED

Ss No.	Sex	Age in Months	Cognitive Development		Content Achievement		Inquiry Skills Achievement		Intelligence Quotient	
			Pre	Post	Pre	Post	Pre	Post	Pre	Post
45	F	179	11	8	57	65	34	46	113	118
46	F	188	10	10	42	66	40	36	101	103
47	F	191	13	11	49	81	46	51	136	140
48	M	185	12	9	42	66	38	40	117	111
49	M	186	9	11	36	56	34	31	94	98
50	F	183	9	10	25	63	27	43	117	115
51	F	180	11	12	45	66	30	43	106	107
52	M	190	10	10	54	71	35	35	110	111
53	M	189	5	6	37	23	8	28	71	77
54	M	191	11	12	49	77	32	25	108	108
55	F	188	11	12	58	72	43	46	116	116
56	M	187	11	14	54	77	42	46	111	105
57	M	189	12	10	48	77	43	38	107	118
58	F	165	12	14	53	82	51	50	137	124
59	F	188	9	7	23	40	36	42	104	120
60	F	181	9	11	58	70	48	48	118	127
61	M	154	8	8	40	75	39	45	124	118
62	F	183	6	6	30	53	41	44	97	108
63	F	179	10	11	53	62	43	42	107	114
64	F	178	4	8	48	40	35	41	102	108
65	F	194	8	7	37	41	37	30	92	93
66	M	177	11	11	46	62	34	49	117	120
67	F	187	9	10	56	65	37	40	118	109
68	M	183	6	6	33	46	24	35	100	96
69	M	185	13	14	52	72	39	38	110	110
70	F	189	11	13	47	72	54	47	120	127
71	M	183	9	8	17	56	20	42	95	101
72	F	188	13	14	63	92	42	41	123	128
73	M	189	12	14	46	68	32	35	101	100
74	F	187	7	9	40	60	42	37	108	111
75	M	182	5	9	36	53	29	37	100	99
76	M	192	12	14	44	61	47	48	106	129
77	M	191	6	6	37	59	37	42	89	109
78	F	182	10	12	41	59	25	41	106	103
79	F	188	5	4	25	50	36	45	95	89
80	F	186	5	10	30	64	36	34	99	100
81	F	182	13	12	30	84	39	48	116	115
82	F	188	6	7	40	56	35	48	102	99
83	F	183	6	7	37	68	35	41	114	105
84	M	184	6	6	44	43	32	36	88	93
85	M	189	12	12	25	73	41	41	102	108
86	M	192	6	8	41	56	35	43	93	95
87	F	181	6	10	44	58	35	40	103	97
88	F	184	5	6	45	41	34	35	84	88

TABLE 3-1 CONTINUED

Ss No.	Sex	Age in Months	Cognitive Development		Content Achievement		Inquiry Skills Achievement		Intelligence Quotient	
			Pre	Post	Pre	Post	Pre	Post	Pre	Post
89	M	188	12	11	54	85	44	47	123	130
90	F	182	10	10	51	72	31	36	115	115
91	F	186	10	13	40	58	29	38	101	105
92	F	181	6	8	46	65	38	44	106	117

The ninety-two subject sample contained thirty-seven males and fifty-five females. The mean age at the beginning of the school year was 185.13 months ranging from 154 months to 194 months. The means and standard deviations of the dependent variables are presented in Table 3-2 and the means are shown in Graph 3-1.

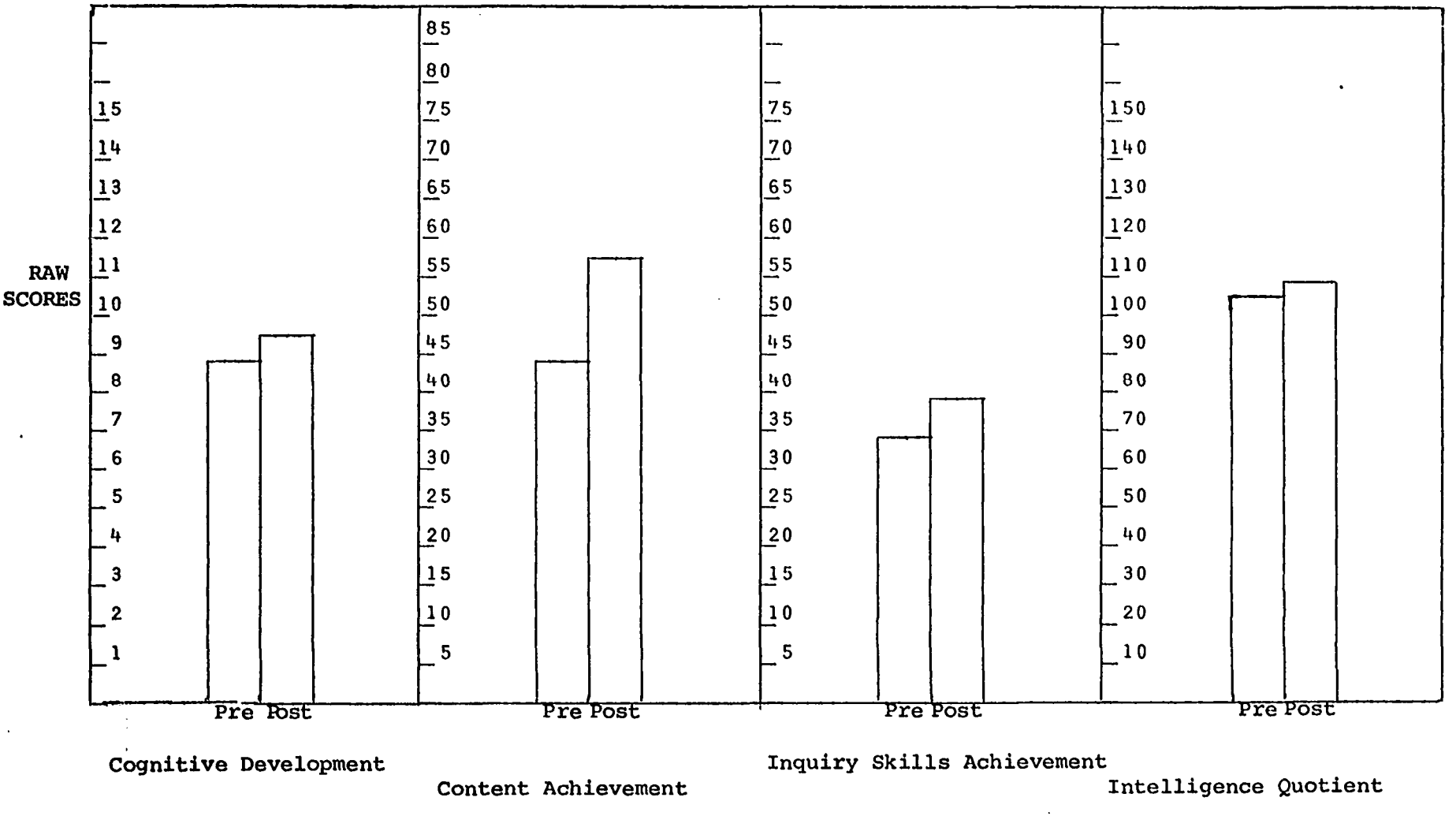
TABLE 3-2

MEANS AND STANDARD DEVIATIONS ON PRETESTS AND POSTTESTS OF COGNITIVE DEVELOPMENT, CONTENT ACHIEVEMENT, INQUIRY SKILLS ACHIEVEMENT, AND INTELLIGENCE QUOTIENT

Statistic	Cognitive Development		Content Achievement		Inquiry Skills Achievement		Intelligence Quotient	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mean	9.01	9.97	44.50	62.29	35.82	40.60	106.68	108.83
Standard Deviation	2.52	2.42	10.10	13.38	7.93	6.03	12.51	12.54

GRAPH 3-2

PRETESTS AND POSTTESTS MEAN SCORES OF COGNITIVE DEVELOPMENT, CONTENT ACHIEVEMENT, INQUIRY SKILLS ACHIEVEMENT, AND INTELLIGENCE QUOTIENT



In section A the main premise of this research was that the inquiry treatment would significantly increase intellectual development, content achievement, inquiry skills achievement, and intelligence quotient. If that premise is true then the posttest scores should increase significantly from the pretest scores. Pretest-Posttest scores were analyzed with a matched pairs t-test. See Chapter II, "Data Analysis Tools," for the appropriate statistical test. The results are shown in Table 3-3.

TABLE 3-3

THE t-TEST OF THE DIFFEPENCES BETWEEN PRETEST AND POSTTEST SCORES

variable	t
Cognitive Development	5.227
Content Achievement	13.548
Inquiry Skills Achievement	6.356
Intelligence Quotient	2.794

The term "significant" is used here with the understanding that the levels of significance for each of the variables will be reported. The reader is left to decide whether or not that particular level is sufficient for the intended purpose. Again, Type II error was considered to be the more serious in this research. All of the values in Table 3-3 are significant at least at the .01 level, therefore, Hypotheses I, II, III, and IV which state the inquiry

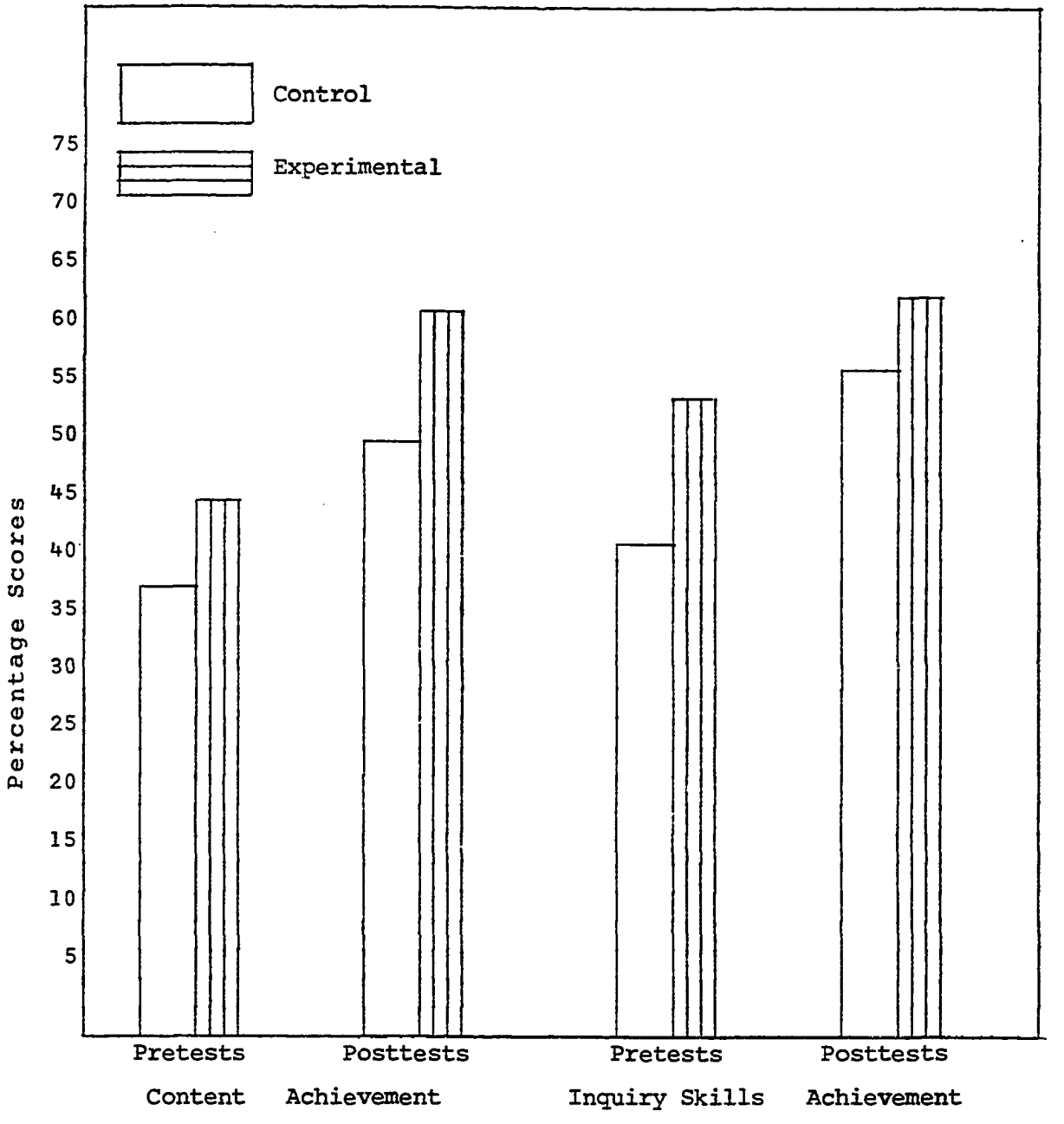
treatment does increase intellectual development, IQ, content achievement, and inquiry skills achievement, respectively, must be accepted.

The remainder of this section compares the control group and experimental group. A description of these two groups is found in Chapter II, "Description of the Experimental Treatment" and "Design of Study." Graph 3-2 presents a comparison of the mean percentage scores of control and experimental groups on achievement in content and inquiry skills.

The control group had a 11.8% increase in content achievement while the experimental group had a 17.4% increase. With respect to inquiry skills, the control group had a greater percentage (16.6%) increase than the experimental group (7.2% increase), although the experimental group began much more proficient in inquiry skills and also posttested 4.7% higher on the EIB than the control group. An explanation of these results is in Chapter IV.

GRAPH 3-2

COMPARISON OF PRETESTS AND POSTTESTS
PERCENTAGE MEANS ON CONTENT
ACHIEVEMENT AND INQUIRY
SKILLS ACHIEVEMENT



Section B

In the second stage of data analysis, a 10 x 10 correlation matrix was computed to determine if any significant relationship exists between sex, age, pre- or post-cognitive development, pre- or post-content achievement, pre- or post-inquiry skills achievement, or pre- or post-IQ. Values in Table 3-4 greater than ±0.267 reflect statistically significant correlations at at least the .01 level of confidence with the df at 90. When a relationship exists between the two variables under examination the Pearson product-moment correlation coefficient is equivalent to or greater than ±0.267.

The symbols used in Table 3-4 to label the columns are explained below:

Pr = Pretest

Po = Posttest

CD = Cognitive Development

CA = Content Achievement

IA = Inquiry Skills Achievement

IQ = Intelligence Quotient

TABLE 3-4

PEARSON PRODUCT-MOMENT CORRELATIONS OF TEN VARIABLES

Variables	Sex	Age	PrCD	PoCD	PrCA	PoCA	PrIA	PoIA	PrIQ	PoIQ
Sex	1.000	-.092	-.253	-.150	-.087	-.067	.054	.182	.093	.076
Age		1.000	.037	-.054	.008	-.117	-.062	-.216	-.296	-.206
PrCD			1.000	.744	.303	.595	.300	.218	.559	.504
PoCD				1.000	.328	.554	.272	.184	.500	.468
PrCA					1.000	.446	.527	.133	.442	.359
PoCA						1.000	.556	.404	.765	.729
PrIA							1.000	.487	.574	.550
PoIA								1.000	.485	.501
PrIQ									1.000	.826
PoIQ										1.000

At the .01 confidence level sex and age correlated with none of the other variables with one exception. Pretest intelligence quotient negatively correlated with age meaning the younger students performed predictably better. The remaining eight variables correlated ($p < 0.01$) with each other in every case with the exception of posttest inquiry skills achievement. This parameter did not correlate with pre- nor posttest cognitive development nor pretest content achievement. A complete discussion and interpretation of the relationships of the variables is in Chapter IV.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF THE DATA

Subdivisions of Chapter IV correspond directly to the subdivisions of Chapter III. Section A presents the interpretation of data from the experimental investigation of the inquiry teaching methodology. Section B is an interpretation of the data from the descriptive investigation of correlations between cognitive development, content and inquiry skills achievement, and IQ.

Section A

Data were gathered to allow the following question to be answered: How can intellectual development, content achievement, inquiry skills achievement, and IQ be affected by the inquiry teaching methodology? The reader is reminded that data from a control group was used with only content and inquiry skills achievement.

An examination of Table 3-2 and Graph 3-1 indicates an increase in all four parameters from the beginning to the end of the experimental treatment. Furthermore these gains were found to be significant at less than the 0.01 level and are presented in Table 3-3. Content achievement has the

greatest increase with a t-ratio of 13.548, succeeded by inquiry skills achievement with a t-ratio of 6.356, cognitive development with t equaling 5.227, and IQ with a t-ratio of 2.794.

Cognitive development increased 6.4% and has a t-ratio of 5.227 which is significant at less than the 0.01 level of confidence. On the basis of those data the hypothesis (Hypothesis I, Chapter II) advancing that subjects taught by the inquiry methodology experience a significant increase in intellectual development can be accepted.

The mean intelligence quotient of the experimental group increased from 106.68 to 108.83. That gain has a t-ratio of 2.794 which is significant at the 0.01 level of confidence. On the basis of those data the hypothesis (Hypothesis II, Chapter II) advancing that subjects taught by the inquiry methodology experience a significant increase in IQ can be accepted.

Again the reader is reminded that inferential statistics could not be employed when comparing the experimental and control groups in content achievement since the examinations are not identical. The judgement of the researcher is that the percentage comparison of the test results is valid since the content instruments are similar. That similarity is discussed in Chapter II. Content achievement of the experimental group was compared to the control group in Graph 3-2. The experimental group has a 17.4% increase in content achievement

while the control group has a 11.8% increase. The pretest to posttest gain of the experimental group has a t-ratio of 13.548 which is significant at less than the 0.01 level of confidence. On the basis of these data the hypothesis (Hypothesis III, Chapter II) advancing that subjects taught by the inquiry methodology experience a significant increase in content achievement can be accepted.

With respect to inquiry skills achievement the comparison between the control group's performance and the experimental group's performance on the EIB is prefaced with this explanation. The experimental group pretested far superior to the control group therefore providing the experimental group with less opportunity for an increase on the EIB. This superior proficiency of the experimental group could be attributed to the inquiry teaching programs established in many of the preceding grades within the school system from which the experimental group was sampled. Also influencing this progress of inquiry development could be the school system's philosophy which professes inquiry as the teaching methodology. The control group showed a greater pretest to posttest gain than the experimental group because of this initial difference in pretests. Although both groups showed significant increases in inquiry skills the experimental group posttested 4.7% higher than the control group. The pretest to posttest gain of the experimental group on the EIB proved to be a significant ($t = 6.356$) increase at less than

the 0.01 level of confidence. On the basis of that data the hypothesis (Hypothesis IV, Chapter II) advancing that subjects taught by the inquiry methodology experience a significant increase of inquiry skills achievement can be accepted.

Section B

Data were gathered to provide evidence for the question: How are intellectual development, content achievement, inquiry skills achievement, and IQ interrelated? A data analysis of the variable comparisons precedes the interpretation.

The 10 x 10 correlation matrix shown in Table 3-4 contains Pearson's product-moment coefficients of the ten dependent variables. The following interpretations are made comparing the variable in each row of Table 3-4 with the other variables listed by columns.

Sex correlated with none of the other variables at the 0.01 level but at the 0.05 level sex correlated ($r = -0.253$) with pretest cognitive development in favor of the males. At the beginning of the experimental treatment the males in the experimental group exhibited formal operations thinking slightly more often than did the females yet after the treatment there existed no significant difference between males and females in intellectual development.

Age correlated ($p < 0.01$) negatively with pretests of IQ ($r = -0.296$) indicating the younger students performed predictably better on the IQ pretests. With alpha at 0.05 age

also negatively correlated with posttest of inquiry skills and IQ. In other words after the experimental treatment the younger students scored higher on inquiry skills achievement ($r = -0.216$) and IQ ($r = -0.206$) than they did on pretests of these parameters. These correlations are not great but this question can be raised: What factors influenced the greater performance of the younger students on the IQ test and inquiry skills test?

Pretest and posttests of cognitive development correlated ($p < 0.01$) with pre- and posttests of content achievement, pretests of inquiry skills achievement, and pre- and posttests of IQ. At the 0.05 level pretests of cognitive development also correlated with posttests of inquiry skills achievement (refer to Table 3-4, page 37 for the correlation coefficients of the aforementioned variable intellectual level is a reliable predictor of and is associated with achievement and IQ. The subjects of the sample that exhibit formal operational thinking score higher on content, pre-inquiry skills, and IQ tests. The researcher advances two interpretations from these results. As subjects progress from concrete-to transitional- to formal-operations they acquire greater conceptual and factual knowledge, they are more proficient with inquiry skills, and they possess an increased verbal and symbolic capacity. Secondly, the test instruments contain some questions that require formal operational logic to solve, therefore, it is anticipated that the formal

operational students would score higher than the concrete operational subjects on these items.

Pretests of content achievement correlated with posttests of content achievement ($r = 0.446$), pretests of inquiry skills achievement ($r = 0.527$), and pretests ($r = 0.442$) and posttests ($r = 0.359$) of IQ with $p < 0.01$. The only parameter with which no correlation occurred, other than sex and age, was posttests of inquiry skills achievement. Posttests of content achievement correlated with every parameter (excluding sex and age) at less than the 0.01 level. Content achievement is a reliable predictor of cognitive development ($r = 0.554$), inquiry skills achievement ($r = 0.404$) and IQ ($r = 0.729$) and tests to have a high association with these variables. Higher posttest scores on the content examination of the experimental group correlates with higher cognitive development, inquiry skills achievement, and IQ.

Inquiry skills achievement does not correlate as highly nor as regularly with the other parameters as does intellectual development, content achievement, nor IQ, therefore, it is not as reliable a predictor of the other parameters. Posttests correlated ($p < 0.01$) with only IQ ($r = 0.501$), pretests of inquiry skills achievement ($r = 0.487$) and posttests of content achievement ($r = 0.404$). Pretests of inquiry skills achievement correlated ($p < 0.01$) with all the other variables except sex and age. Performance on posttests of inquiry skills achievement determined with the EIB is not

associated with nor a reliable predictor of cognitive development nor pretest content achievement. The subjects' inquiry skills at the end of the experimental treatment are not significantly different among the cognitive developmental periods. Concrete operational students possess varying degrees of inquiry skills as do transitional operational subjects and formal operational subjects. This trend is the same with content achievement at the beginning of the experimental treatment. Conversely the subjects with greater skills of inquiry achieved higher scores on the pre- and post-IQ tests. Furthermore, subjects that are more skilled in inquiry have greater conceptual and factual knowledge at the termination of the experimental treatment.

IQ, as determined with the SFTAA, is associated with and is a reliable predictor of all the other parameters except sex. These associations are significant at less than the 0.01 confidence level with one exception. Posttests of IQ and age do not correlate while pretests of IQ and age negatively correlate ($r = -0.296$) in favor of the younger students. The subjects exhibiting greater content knowledge and inquiry skills achieved higher IQ scores as did the more formal operational students. Posttests of content achievement correlated very highly with pre- and posttests of IQ ($r = 0.765$ and $r = 0.729$ respectively). This IQ instrument favors the more intelligent students!

Frequently the question is asked regarding the relationship between IQ and level of intellectual development as measured with the Piagetian tasks. The data from this study demonstrated that the coefficient of correlation relating those two factors is 0.468. While that correlation coefficient is not high it is positive which probably accounts for the statistically significant relationship found for the correlation between those two variables. The magnitude of the correlation suggest that while IQ and the Piagetian tasks are measuring a common variable, each is probably also measuring at least one other factor. What the other factors being measured are is not known.

The general trends of all these data on correlations reveal that ($p < 0.01$) sex and age correlate with none of the other variables with one exception. Pretests of IQ negatively correlates with age meaning the younger students performed better on these pretests. The remaining eight variables correlated with each other at at least the 0.01 level in every case with the exception of posttests of inquiry skills achievement. This parameter did not correlate with cognitive development nor pretests of content achievement.

On the basis of these data the hypothesis (Hypothesis V, Chapter II) advancing that there are relationships among intellectual development, IQ, and achievement in high school biology students can be accepted.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The intention of this study was to provide evidence for the questions--1) How can intellectual development, achievement, and IQ be enhanced by the inquiry teaching methodology? and 2) How are Piagetian levels of intellectual development, achievement, and IQ interrelated? Data in the tables and graphs of Chapter III support these conclusions:

1. The inquiry teaching methodology does promote cognitive development of high school biology students in the experimental group. A recapitulation of the scoring of cognitive development is presented to clarify this conclusion. A total score of four through eight on the four tasks represents the concrete operational period. A total score of nine through eleven represents transitional operational thinking and a total score of twelve through fifteen represents formal operational logic. The transitional period is a stage of development that is neither fully concrete nor fully formal operational as measured with the four Piagetian tasks--Conservation of Volume, Separation of Variables, Combinations of Colorless Chemical Liquids and Ratios. A complete explanation of the scoring for each task is found in Appendix D. On

pretests of intellectual development, 59.8% of the sample had entered either the transitional period (between concrete and formal operations) or the formal operational period. After the inquiry treatment 71.7% of the sample had at least entered the transitional period between concrete operational and formal operational.

2. The inquiry teaching methodology did increase content achievement in the subjects of this research. The mean score of the experimental group increased significantly when measured with the "Biology Content Examination." These gains proved greater than the control group's gain in content achievement as measured by the Comprehensive Final Examination. Both instruments measured learned conceptual and factual knowledge.

3. The inquiry teaching methodology does enhance inquiry skills achievement. Subjects in the experimental group exhibited significant gains in formulating problems, formulating hypotheses, using science literature, designing an experiment, interpreting data, and synthesizing new knowledge as measured with the "Explorations in Biology."

4. The inquiry teaching methodology does produce gains of IQ scores as measured with the Short Form Test of Academic Aptitude level five. The mean score increased from 106.68 to 108.83 with standard deviations of 12.51 and 12.54, respectively. This gain proved to be significant at less than the .01 level of confidence. In other words the majority of the

experimental group as a whole gained 2.15 points from pre- to post- IQ tests which proved to be significant.

5. There exists correlations between cognitive development and content achievement, cognitive development and inquiry skills achievement except for posttests of these two parameters, and cognitive development and IQ. The factual and conceptual knowledge the students have learned is associated with the operational level in which they have entered. On pretests of cognitive development and content achievement this is a high positive correlation ($r = 0.544$) reflecting that the more formal operational students possess a greater content knowledge than the more concrete operational students. This trend is the same between cognitive development and IQ and, to some degree, between cognitive development and inquiry skills achievement. These data suggest that cognitive development should be an educational goal of prime priority.

6. There exists a correlation between content achievement and IQ. The highest correlation being on the posttests of content achievement and IQ. Subjects with higher IQs scored higher on the "Biology Content Examination" ($r > 0.72$). Content achievement and inquiry skills achievement correlate except for pretests of content achievement and inquiry skills posttests. Stated differently, the degree of content knowledge at the beginning of the school year is not related to success on inquiry skills achievement at the end of the experimental treatment.

7. There is a correlation between inquiry skills achievement and IQ. The higher IQ scores correlate with higher EIB scores. The students with high IQs also had greater achievement of inquiry skills than the students with lower IQs.

The present research has provided evidence to support the conclusions that 1) the inquiry methodology does increase intellectual development, content achievement, inquiry skills achievement, and IQ; and 2) there exist relationships among intellectual development, content achievement, inquiry skills achievement, and IQ. This research and the subsequent conclusions reveal suggestions for further study.

1. How completely are science programs throughout the country implementing the inquiry teaching methodology? How are non-science courses employing the inquiry teaching methodology? This research and research by Friot,[1] McKinnon,[2] and Stafford[3] establishes the inquiry methodology to be a teaching methodology superior to the traditional lecture-demonstration methodology.

2. How is the intellectual level of the learner considered in curricula development? Are concrete operational

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[1]Friot, "Curriculum Experiences and Movement from Concrete-Operational Thought," pp. 79-90.

[2]McKinnon and Renner, "Are Colleges Concerned with Intellectual Development," pp. 1050-1051.

[3]Stafford and Renner, "SCIS Helps the First Grader to Use Logic in Problem Solving," pp. 159-164.

students engaged in concrete experiences, concrete content, and concrete teaching procedures? How are educators involved with intellectual development? Research[4] has shown that not until the students become formal operational do they begin to demonstrate understanding in formal operational concepts. Concrete operational students can understand approximately 30% of concrete operational concepts and little or no formal operational concepts. Other research[5] has shown that students who have entered the formal operational period demonstrate higher levels of achievement while in school if they are taught concretely as opposed to formally.

3. In what other ways are IQ tests valid intelligence measures? This research has shown IQ to be correlated with cognitive development, content achievement, and inquiry skills achievement. How can students' abilities and potentials be accurately determined with conventional IQ tests? How is a student's IQ affected by a traditional teaching methodology? IQ scores have long been exploitative indicies of a student's intellectual profile. How is this statistic an accurate indicator of mental abilities or do better instruments exist to measure intellectual capabilities?

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[4]Lawson and Renner, "Relationships of Science Subject Matter and Developmental Levels of Learners," p. 347.

[5]J. D. Sheehan, "The Effectiveness of Concrete and Formal Instructional Procedures with Concrete- and Formal-Operational Students," (unpublished Ph.D. dissertation, State University of New York, 1970).

4. In what other ways are cognitive development, content achievement, inquiry skills achievement, and IQ interrelated? According to this research there is a high correlation between any two of these variables but what specific associations exist, for example, between content achievement and inquiry skills achievement, or cognitive development and IQ. Are the tests of these parameters measuring similar portions of intelligence? In what other aspects are intellectual development, achievement, and IQ related?

The answers to these questions could have a profound and constructive influence in educational curricula development and implementation.

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APPENDIX A

DESCRIPTION OF THE INQUIRY ROLE APPROACH ROLES

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The Inquiry Role Approach program uses four student roles which enable balanced teamwork to be accomplished. The roles (Discussion Coordinator, Technical Advisor, Data Organizer, and Process Advisor) are described below.

Discussion Coordinator: This person has the responsibility to lead the team in discussions which will answer content questions, e.g. answering laboratory report questions. In laboratory investigations the Discussion Coordinator is responsible for leading the team in writing the title, determining the purpose, and answering the report questions of the experiment.

Technical Advisor: This team member has the responsibility of leading the team in the performance of the experiments by delegating procedural steps (e.g. getting materials, setting up apparatus, and cleaning up).

Data Organizer: The student assuming this role has the responsibility of leading the team members in gathering data (e.g. charts, graphs, tables, and drawings). The Data Organizer presents the team's data to the class.

Process Advisor: This team member maintains a daily log of individual performance on all activities, team

performance of working together, and the ways that any problems were solved. The Process Advisor leads the group in the team's evaluation of each member in the team.

Initially the roles are very structured and mechanical, but as the team becomes familiar with the IRA activities and gains experience the roles become more flexible and overlapping.